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LANDSAT-D
Investigations Workshop

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May 13-14, 1982

Goddard Space Flight Center

Day 1

E83-10241
TM-85374

N83-21482 #

(E83-10241) LANDSAT-D INVESTIGATIONS WORKSHOP (NASA) 266 p HC A12/MF A01 CSCL 05A
N83-21482
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G3/43 00241

Agenda

John Barker

Agenda

LANDSAT-D INVESTIGATIONS WORKSHOP - BLDG. 26, ROOM 205

Thursday, 13 May 1982

8:30 am	Agenda	Barker
8:35 am	Welcome, Science Organization and Introduction of Investigators	Salomonson
9:00 am	Landsat-D Project Status	Busse
9:15 am	Landsat-D Ground Segment	Webb
10:15 am	BREAK (Photo Session)	
10:45 am	Early Access TM Processing	Lyon
11:00 am	Landsat-D Data Acquisition and Availability	Freden
11:30 am	Landsat-D Performance Characterization	Barker
12:00 pm	Introduction of Technical Experts and Science Representatives	
12:30 pm	Lunch and Informal Investigations Team Interaction	

Thursday, 13 May 1982 (Cont.)

2:00 pm	Introduction to MSS Pre-NOAA Characterization	Alford
2:15 pm	MSS Radiometric Sensor Performance • Spectral Information • Absolute Calibration • Ground Processing	Barker
3:30 pm	MSS Geometric Sensor Performance	Banks
4:00 pm	MSS Geometric Processing and Calibration	Brooks
5:00 pm	Closing Remarks	Barker
5:30 pm	Dinner and Informal Investigations Team Interaction	

Thursday, 13 May 1982 (Cont.)

TOURS, etc., Building 28

(Five Tours/Presentations Offered Each Half Hour)

8:30 pm, 9:00 pm, 9:30 pm, 10:00 pm

1.	Landsat Assessment System (LAS)	Lyon/Fischel
2.	Image Generation Facility (IGF)	GE
3.	MSS and TM Sensored Pictures	Barker
4.	Control and Simulation Facility (CSF)	GE
5.	End-to-End System Analysis Study Highlights	Billingsley

Agenda

LANDSAT-D INVESTIGATIONS WORKSHOP

Friday, 14 May 1982

8:00 am	Informal Investigations Team Interaction	
8:30 am	Introduction to TM Characterization	Barker
	TM Radiometric Sensor Performance • Spectral Information • Absolute Calibration • Ground Processing	
10:15 am	BREAK	
10:30 am	TM Geometric Sensor Performance	Engel
11:30 am	TM Geometric Processing — Flight Segment	Beyer
12:30 pm	Lunch and Informal Investigations Team Interaction	

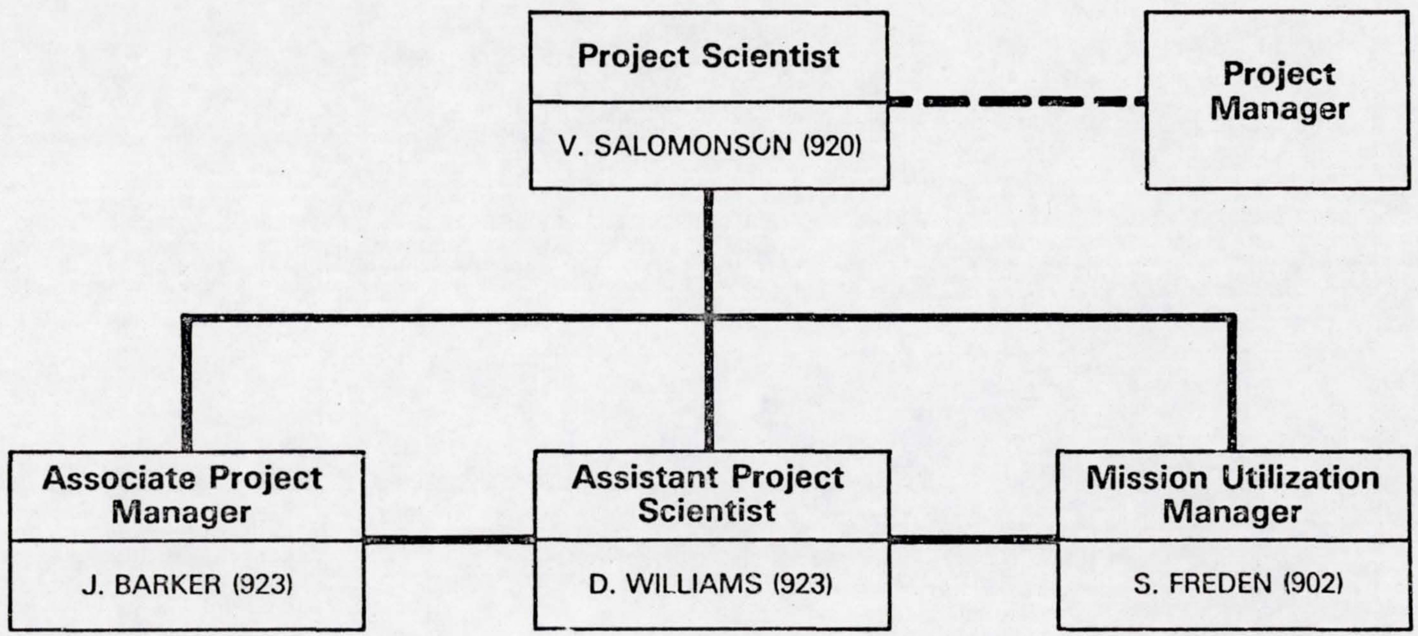
Friday, 14 May 1982 (Cont.)

1:45 pm	TM Geometric Processing — Ground Segment	Beyer
3:00 pm	Early Access TM Processing	Fischel
3:45 pm	Wrap-Up Panel Discussion	Science Team
4:15 pm	Informal Investigations Team Interaction	

Welcome, Science Organization and Introduction of Investigators

Vince Salomonson

Science Office Organization



Distributed Responsibilities

PROJECT SCIENTIST

- Overall Management and Direction of Project Science Activities
- Representation of Science Objectives and Activities to NASA Headquarters, GSFC and the User Community
  - Chairman of Landsat-D Technical Users Working Group

ASSOCIATE PROJECT SCIENTIST

- Day to Day Representation to the Project
- Systems Performance for Flight and Ground Segments
- Systems Contractor Management (Santa Barbara Research Center (SBRC), GE) for Science Contracts

Distributed Responsibilities (Cont.)

ASSISTANT PROJECT SCIENTIST

- Science Monitor
- Science Resources
  - Manpower
  - Dollars

MISSION UTILIZATION MANAGER

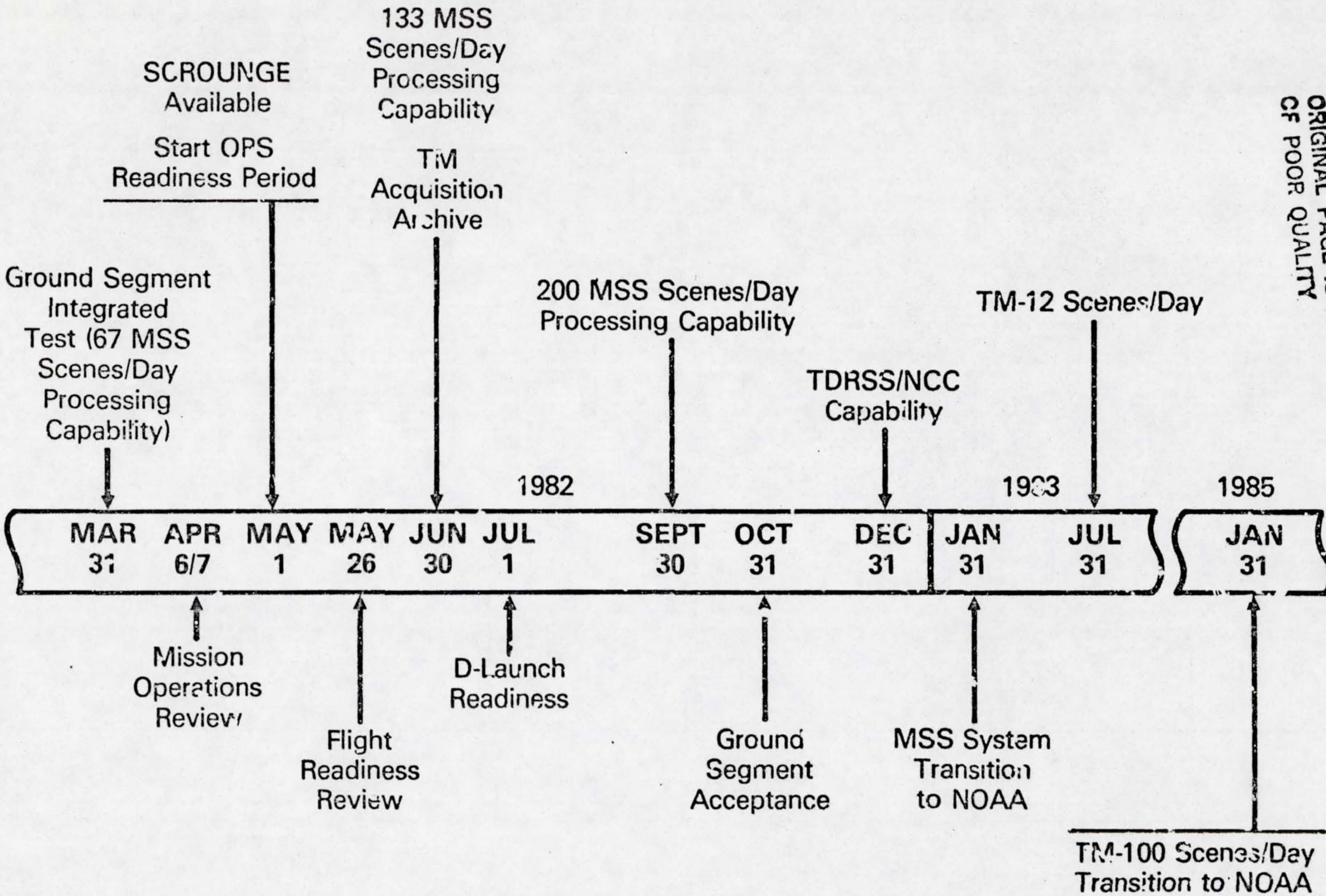
- Scene/Data Selection
  - Acquisition
  - Processing
  - Distribution
- Out-of House Investigators Management
  - Contracts
  - Grants
  - MOU's
  - Scientific Monitors
  - Contract Monitors

All Responsibilities Require Close Contact and Frequent Communication with All Elements of the Project: e.g. LAS, ADDS, Software Manager, Mission Operations Manager, etc.

Landsat-D Project Status

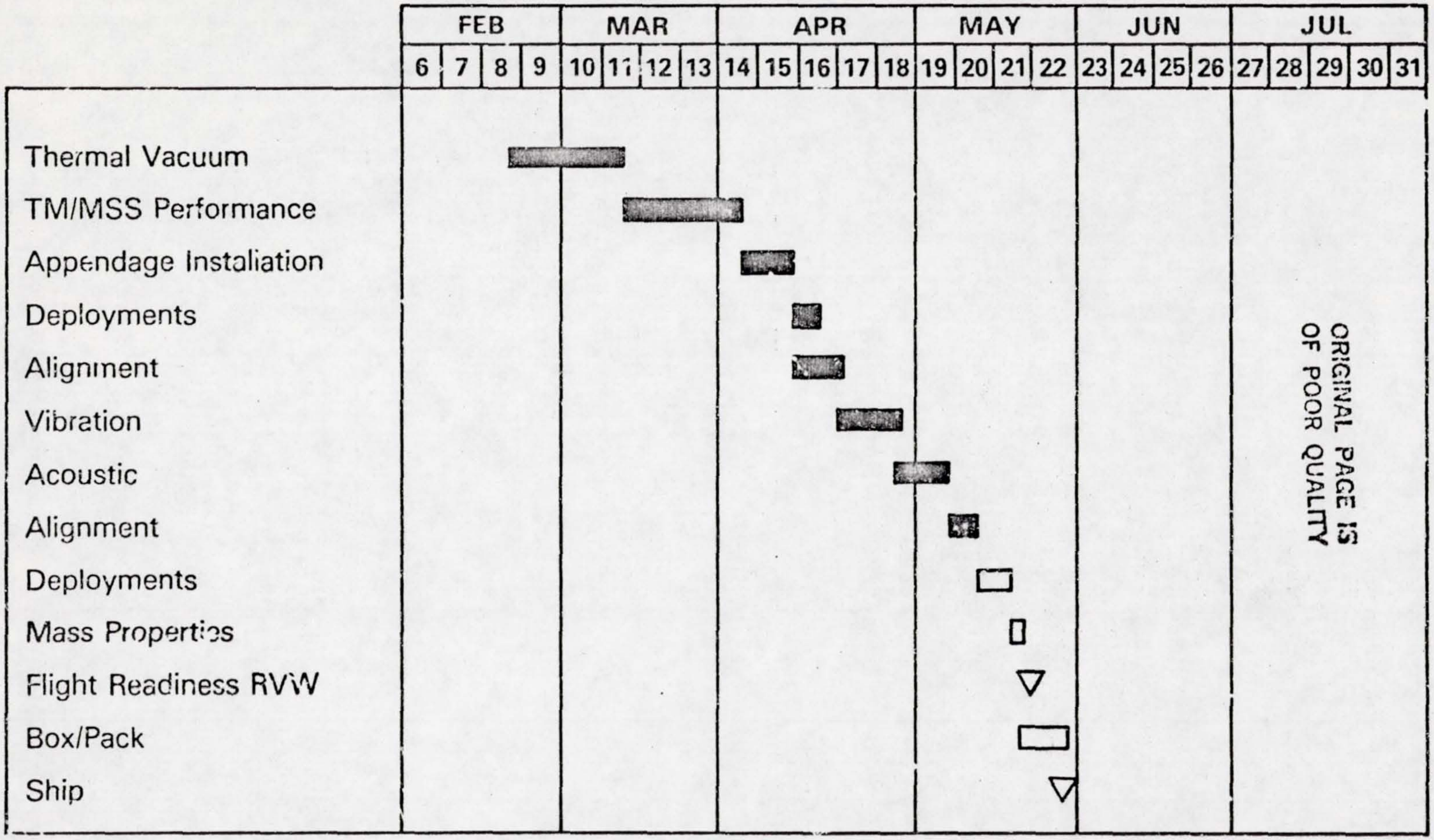
Jon Busse

Landsat-D Key Events



Flight Segment Status

COMPLETED THERMAL VACUUM TEST MARCH 11, 1982



Landsat-D Ground Segment

Bill Webb

Landsat-D System Overview

- System Requirements
- Flight Segment
- Ground Segment

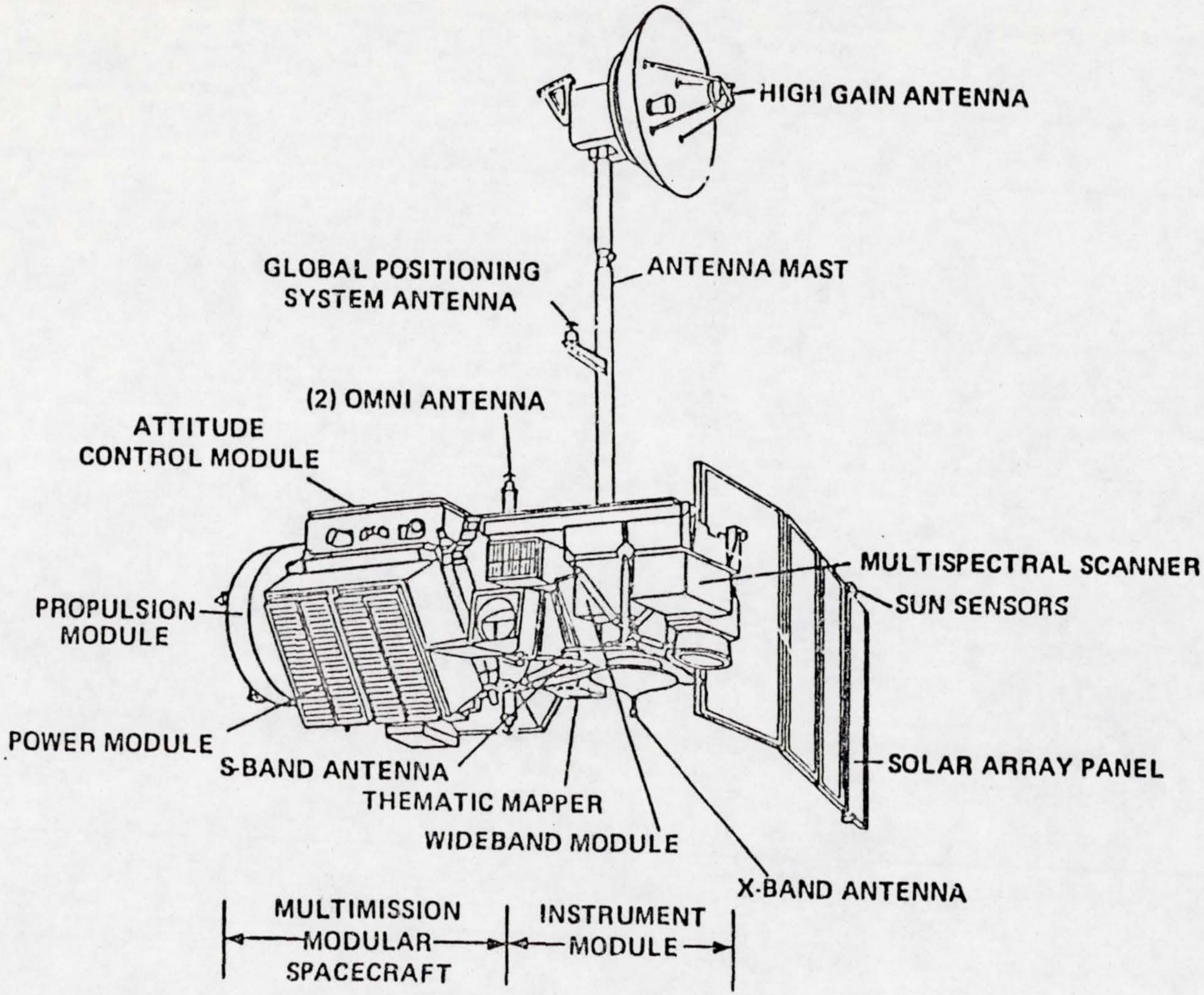
Landsat-D System Requirements

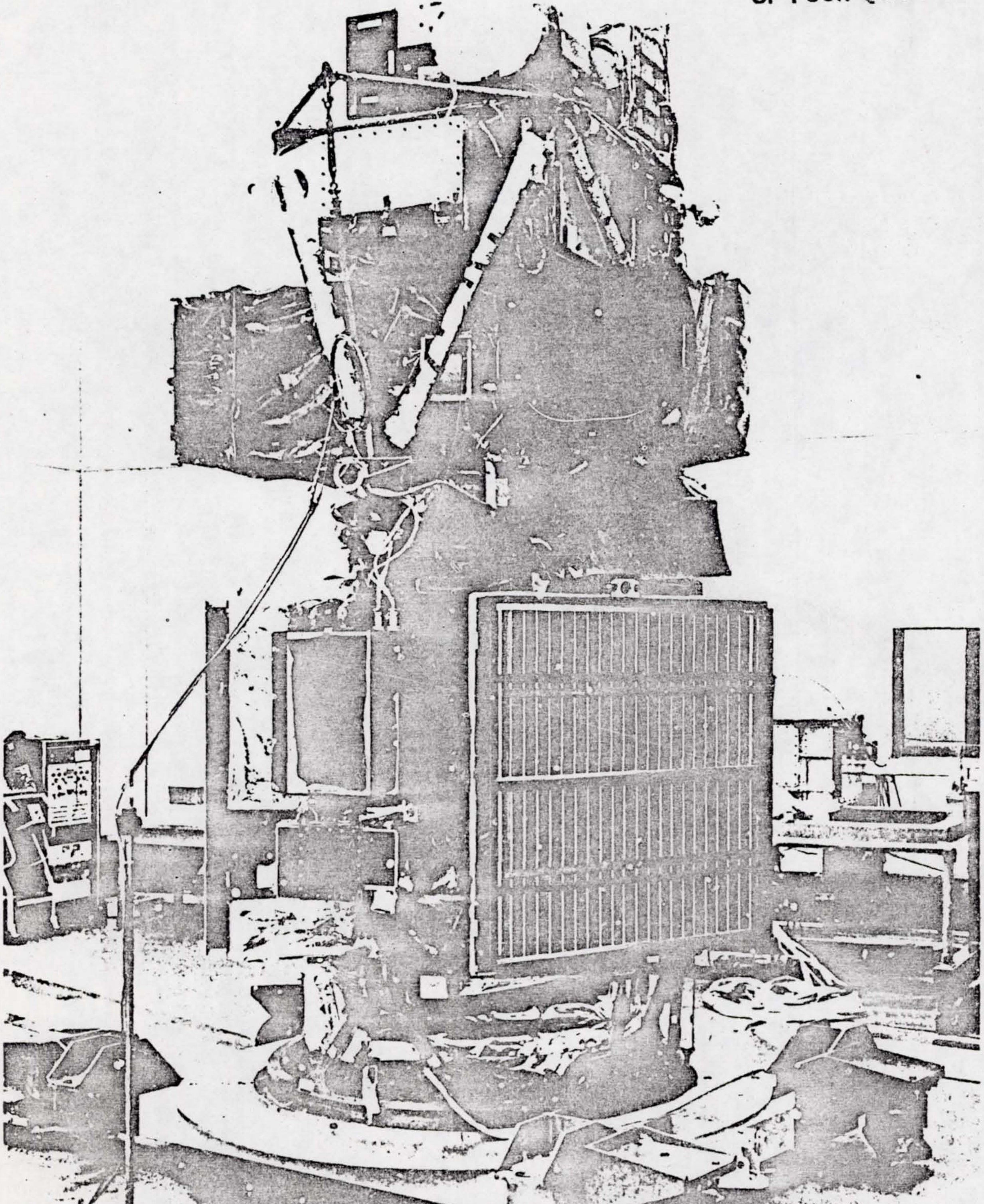
- Orbit
  - Altitude: 705.3 km
  - Descending Node: 9:30-10:00 a.m.
- Launch Vehicle
  - Delta 3920
- Instruments
  - Multispectral Scanner
    - 4 Band
    - 80 Meter IFOV
  - Thematic Mapper
    - 7 Band
    - 30 Meter IFOV
- Flight Segment
  - Uses Multimission Modular Spacecraft
  - Shuttle Retrievable
- Mission Life
  - 3 Years
- 1 Spacecraft Operation at a Time
- Ephemeris Data
  - Global Positioning System
  - Predicted/Uplink
- Coverage
  - Ground Station Tracking Data Network Initially
  - Tracking and Data Relay Satellite System When Available
- Scenes/Day — Flight Segment
  - NASA (200 MSS; 100 TM)
  - Foreign (337 MSS; 150 TM)
- Data Quantity — Ground Segment
  - MSS
    - Archival Data — 200 Scenes/Day
  - TM
    - TM Evaluation—Begins July 30, 1982
      1 Scene/Day
    - TM R&D—Begins July 30, 1983
      Archive Data—12 Scene/Day
      Fully Processed—12 Scene/Day
    - TM Operational— Begins January 31, 1985
      Archive Data—100 Scene/Day
      Fully Processed—50 Scene/Day Film/HDT
      10 Scene/Day CCT

Products Through Ground Segment Within 48 Hours
  - High Density Tapes
  - Computer Compatible Tapes
  - TM Film
- Data Quality
  - Geodetic Accuracy: 0.5 Pixel, 90% of the Time
  - Temporal Registration: 0.3 Pixel, 90% of the Time
  - Radiometric Correction to ± 1 Quantum Level

LANDSAT-D
FLIGHT SEGMENT

LANDSAT D FLIGHT SEGMENT





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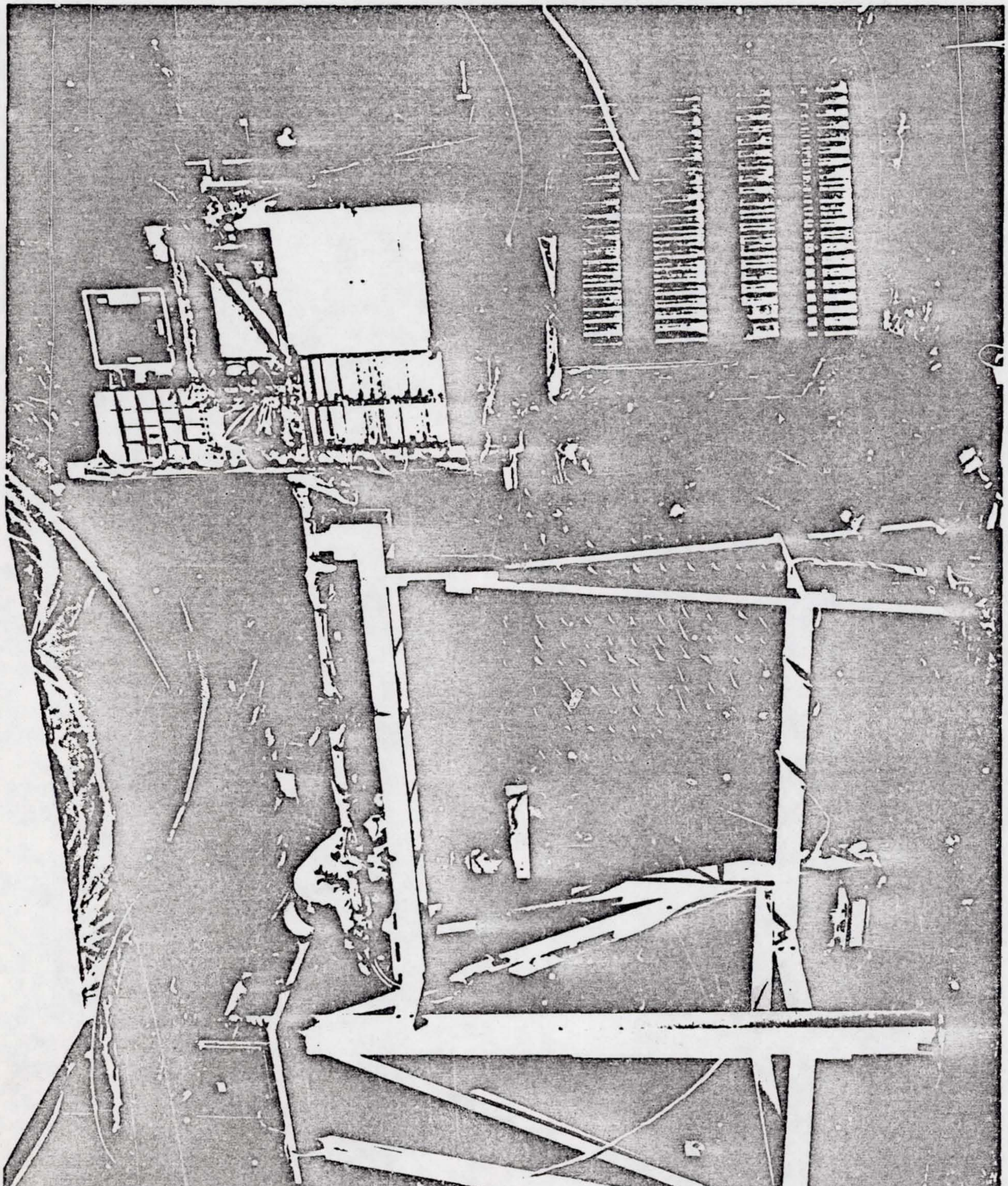
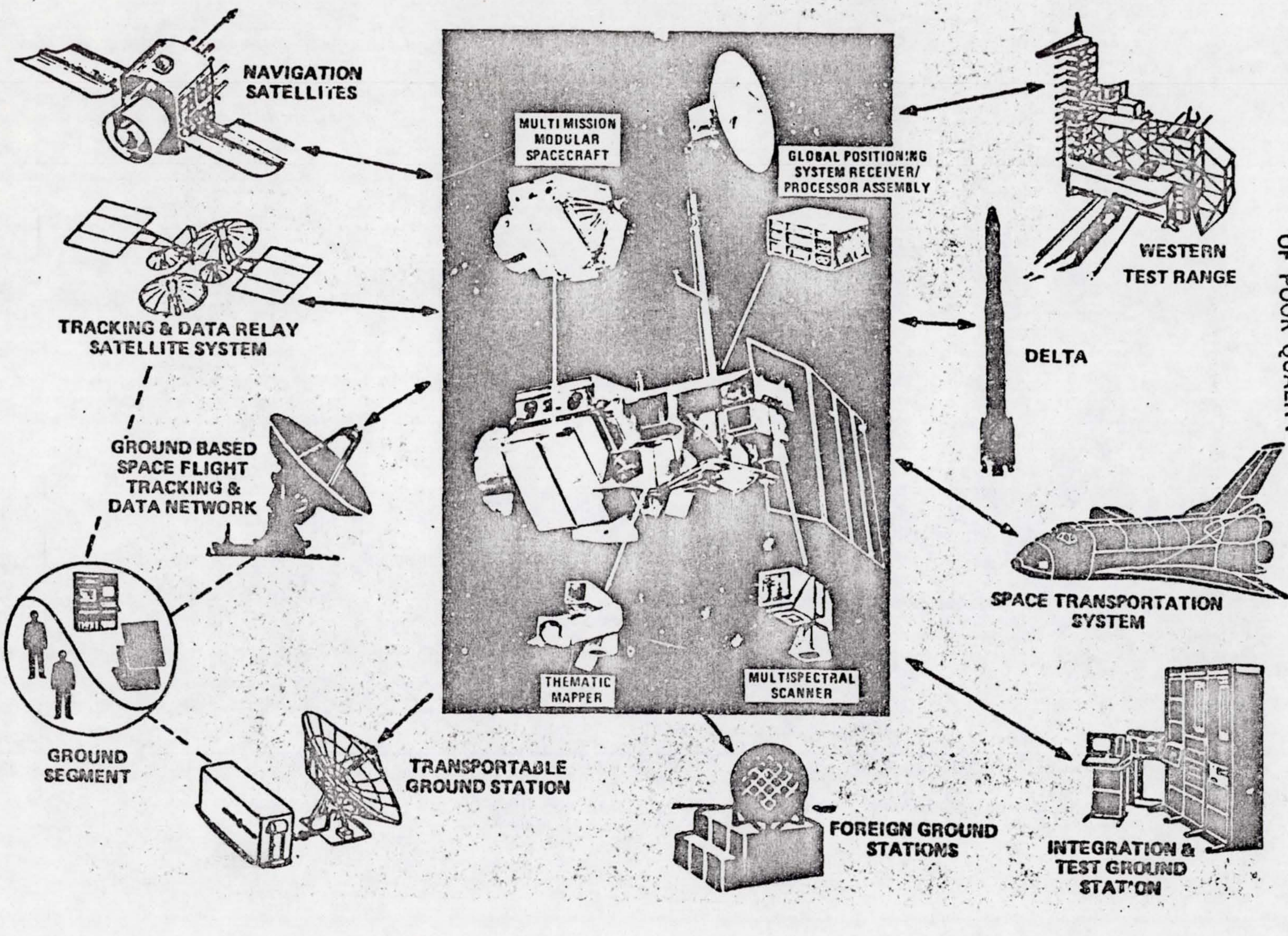
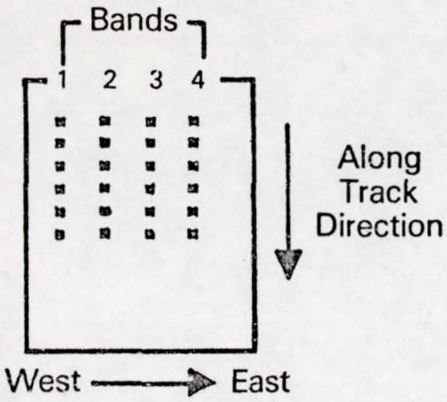


FLIGHT SEGMENT INTERFACES

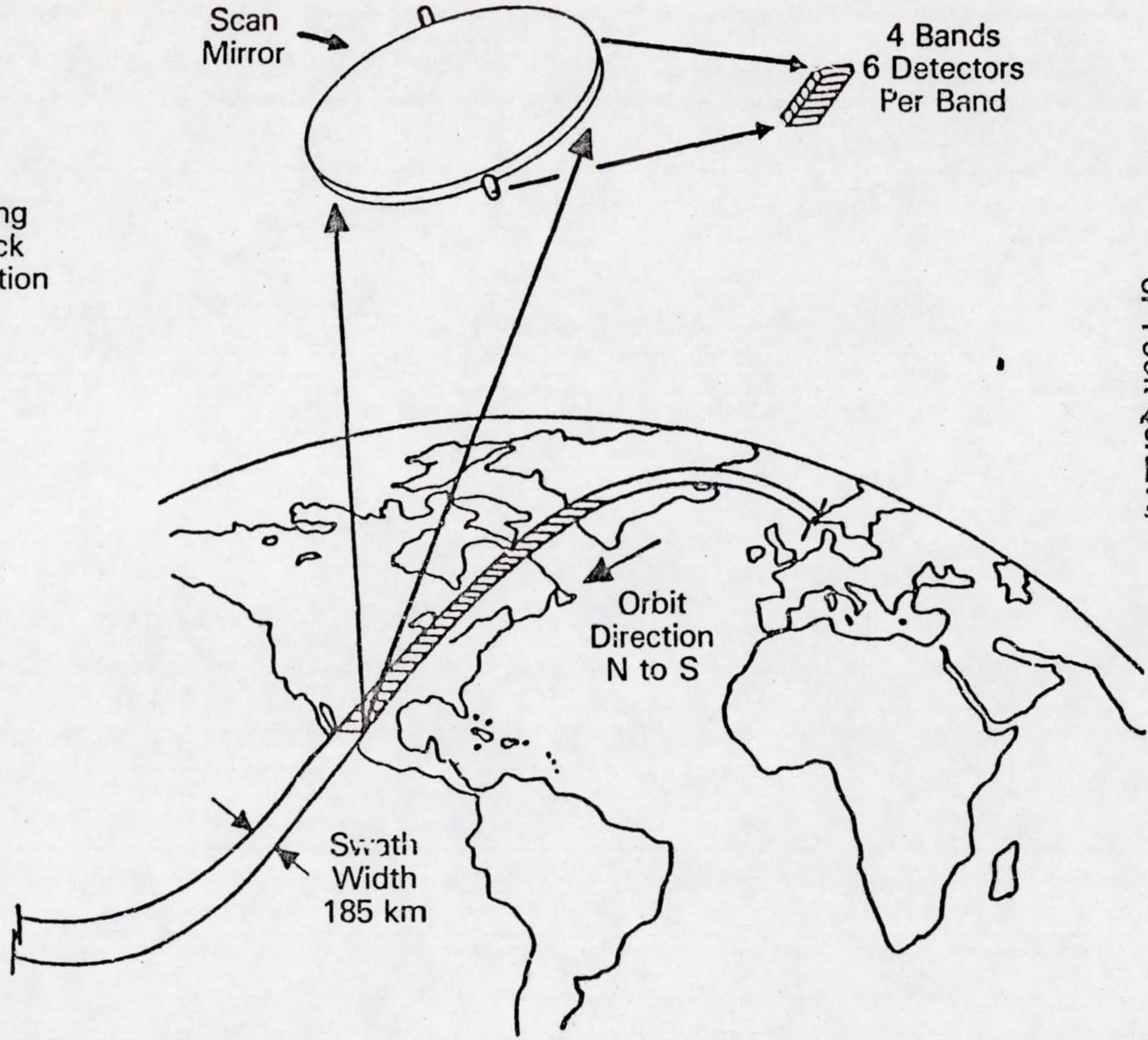


Multispectral Scanner (MSS) Sensor

MSS Detector Details



Scan Direction



Band	Spectral Ranges μm
1	.5 — .6
2	.6 — .7
3	.7 — .8
4	.8 — 1.1

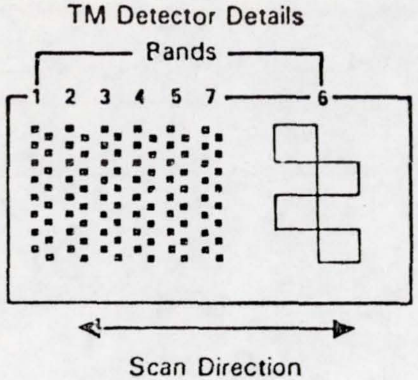
Ground IFOV

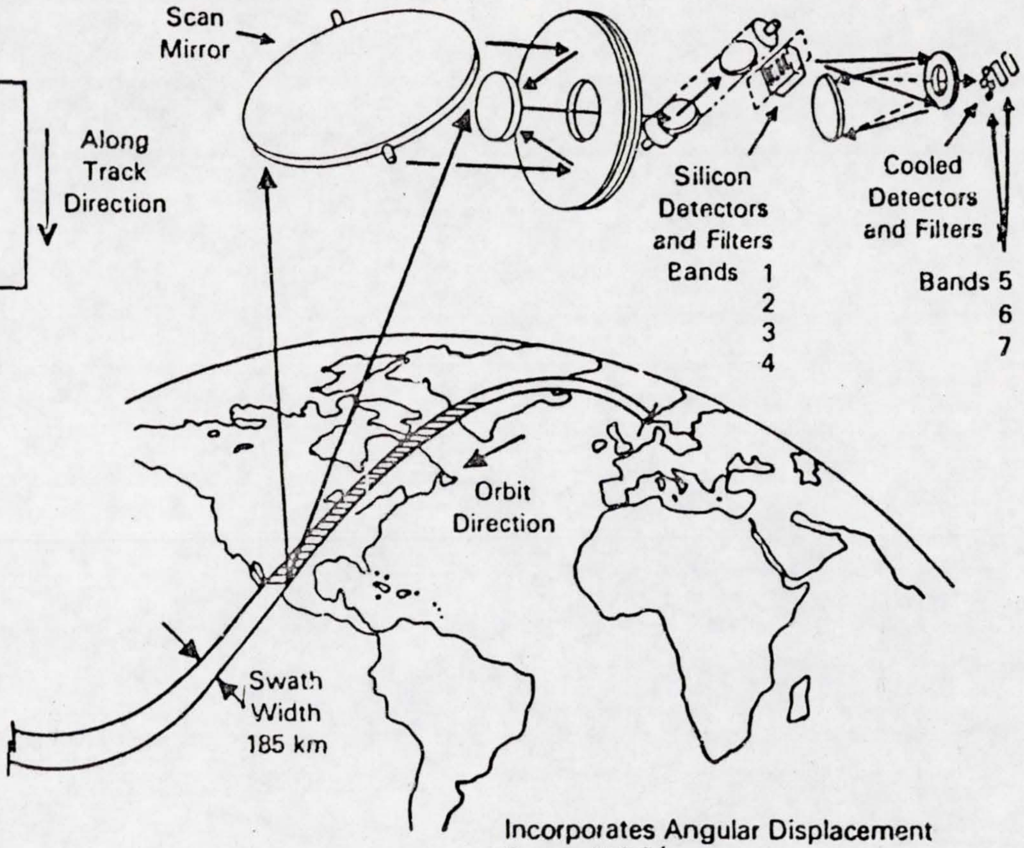
All Bands — 83 Meters

Data Rate — 15.06 Mbps

Quantization Levels — 64

THEMATIC MAPPER (TM) SENSOR





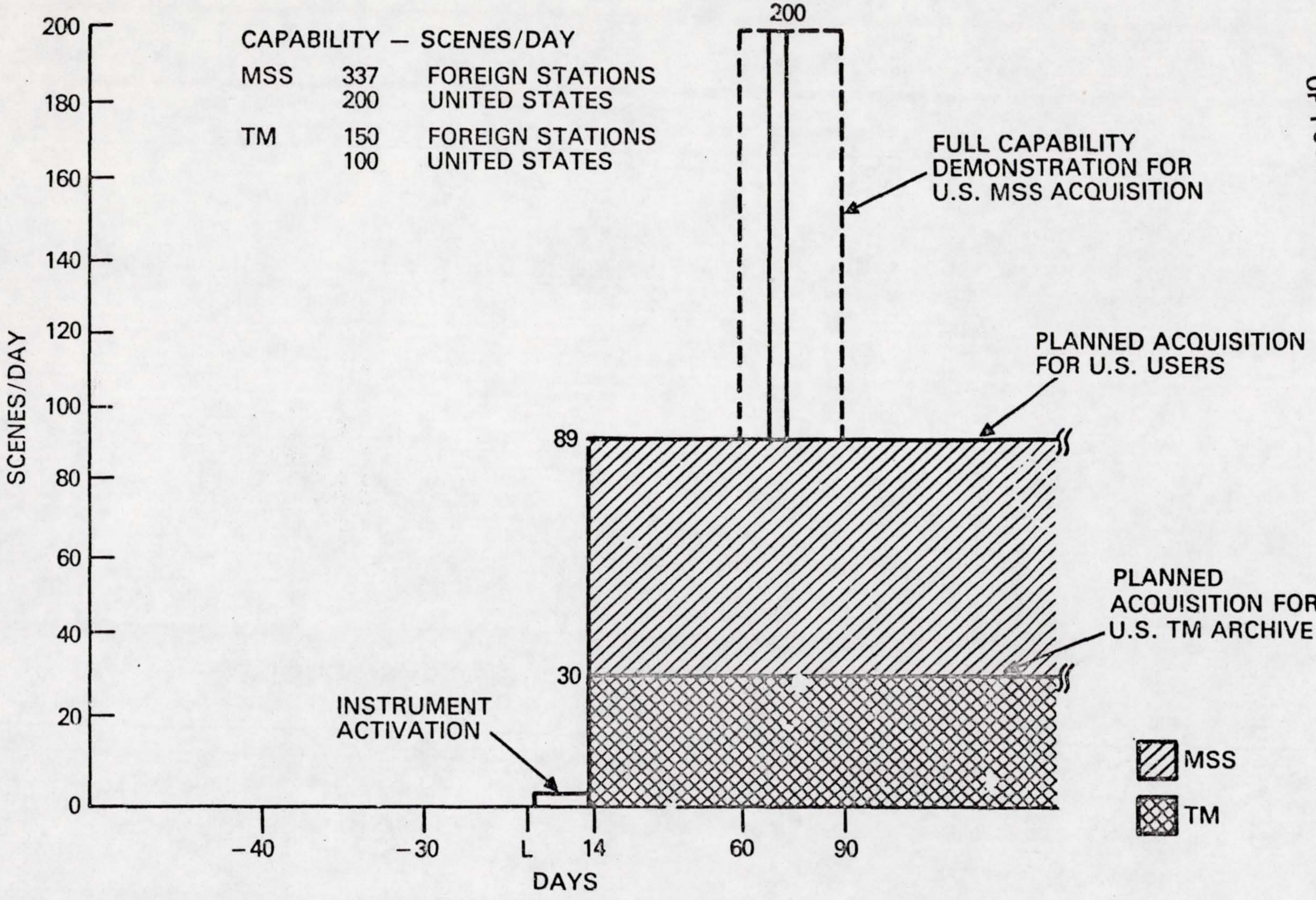
BAND	SPECTRAL RANGES μm
1	45 – 52
2	52 – 60
3	63 – 69
4	76 – 90
5	1 55 – 1 75
6	10 4 – 12 5
7	2 08 – 2 35

Ground IFOV
Bands 1-5 & 7 30 Meters
Band 6 120 Meters

Data Rate – 84.9 Mbps
Quantization Levels – 256

Incorporates Angular Displacement Sensor (ADS)
Measures Angle of Motion from 2 to 125 Hz
Source of Jitter Compensation Data

Acquisition



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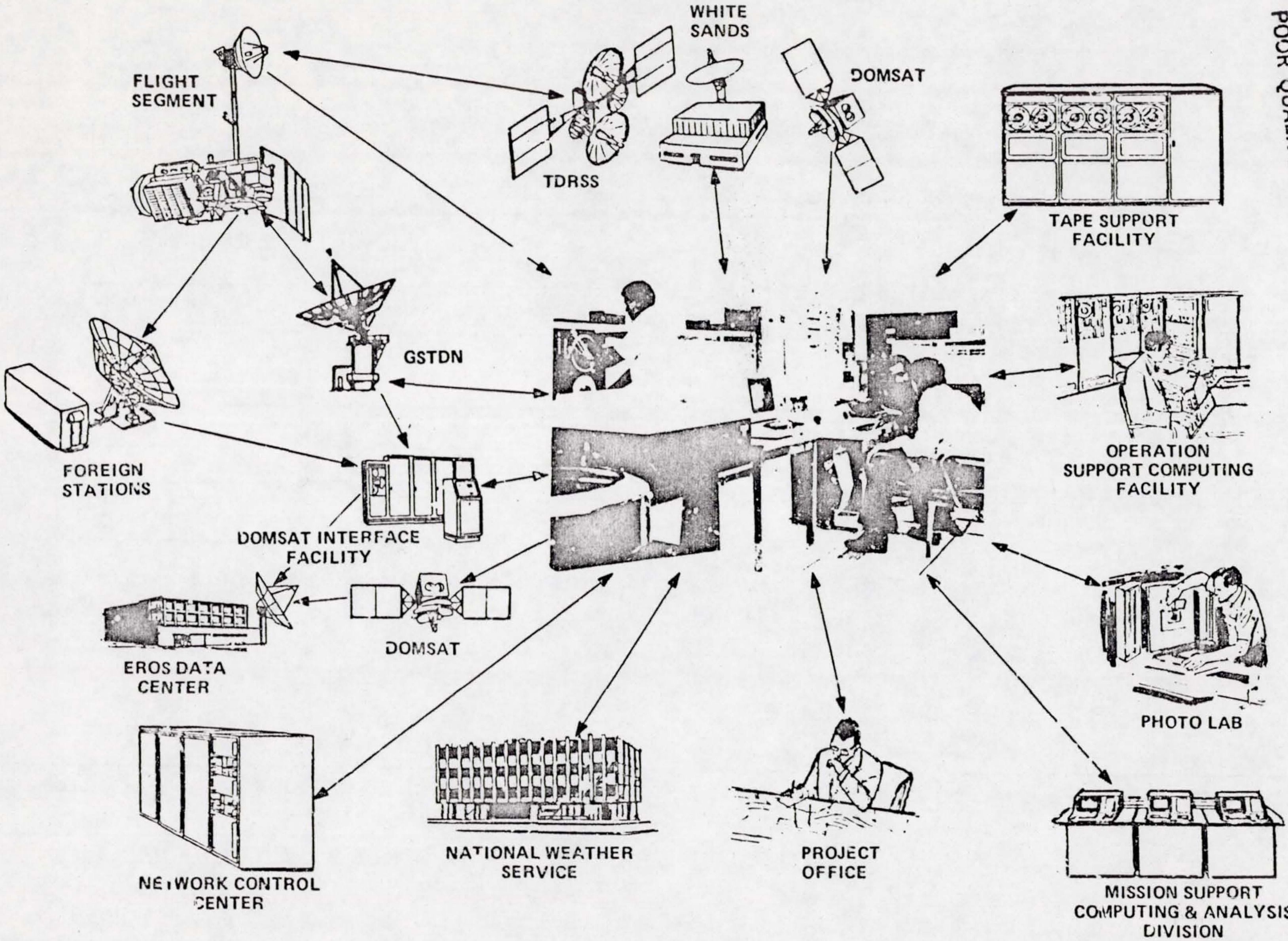
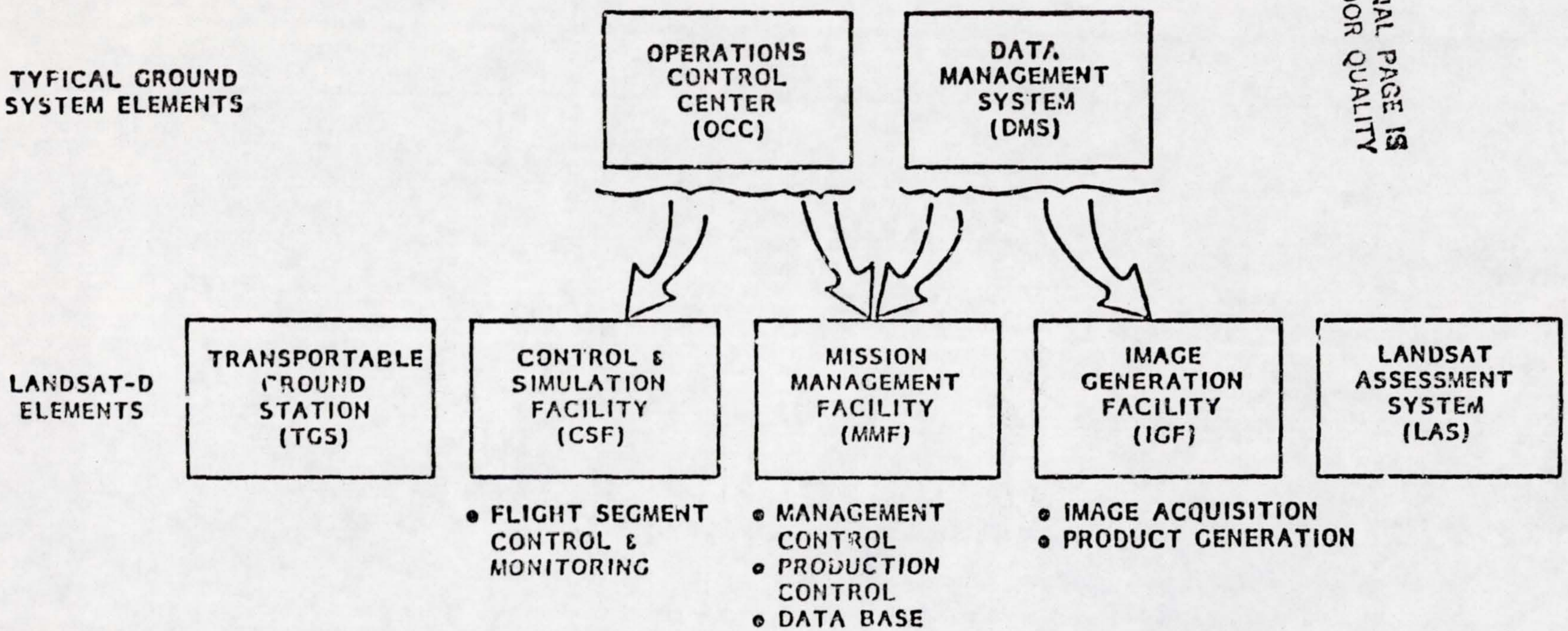
LANDSAT-D
GROUND SEGMENT

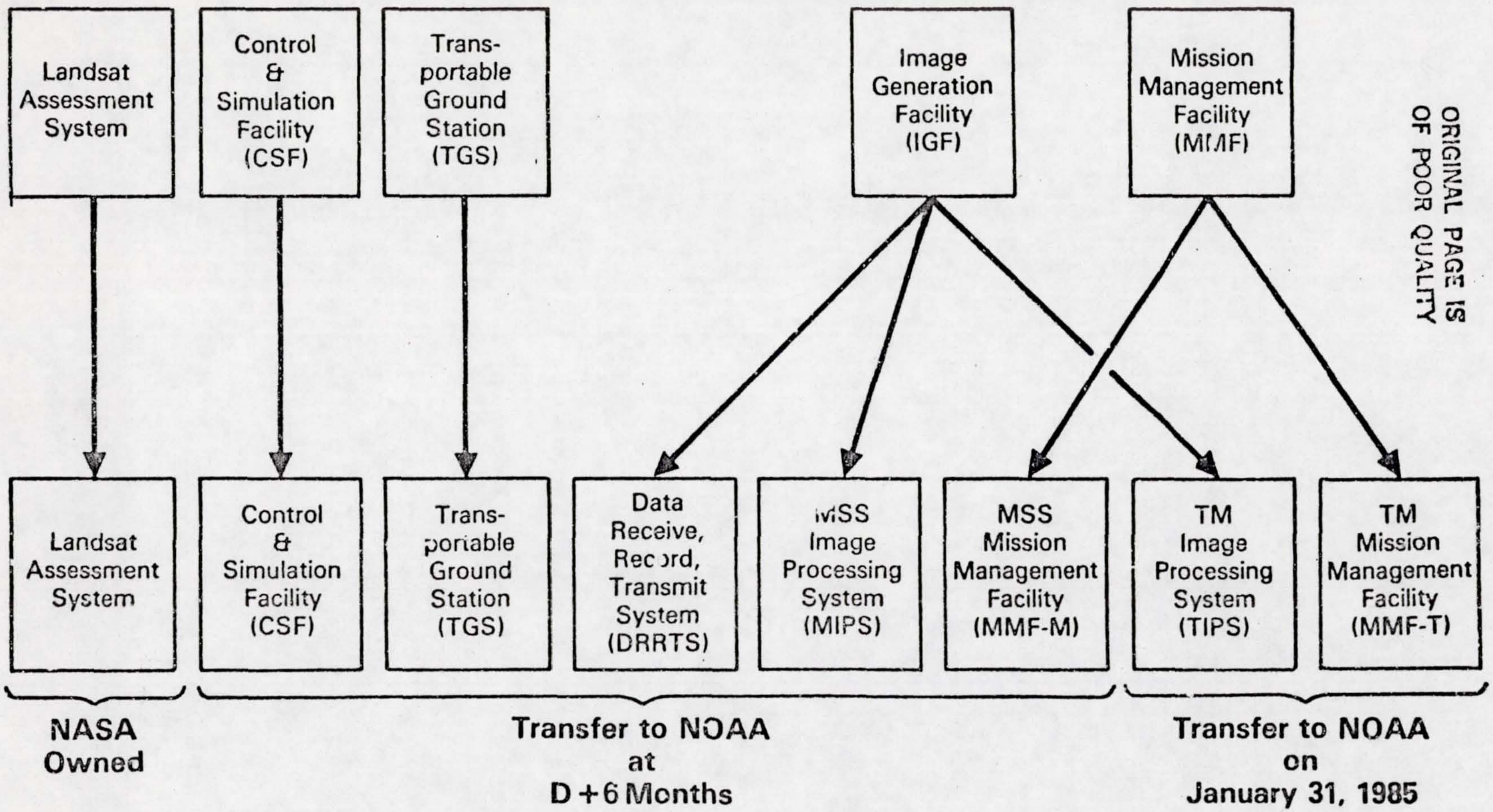
GROUND SEGMENT INTERFACES



PARTITIONING THE GROUND SEGMENT



Mission Management Facility and Image Generation Facility Partitioning



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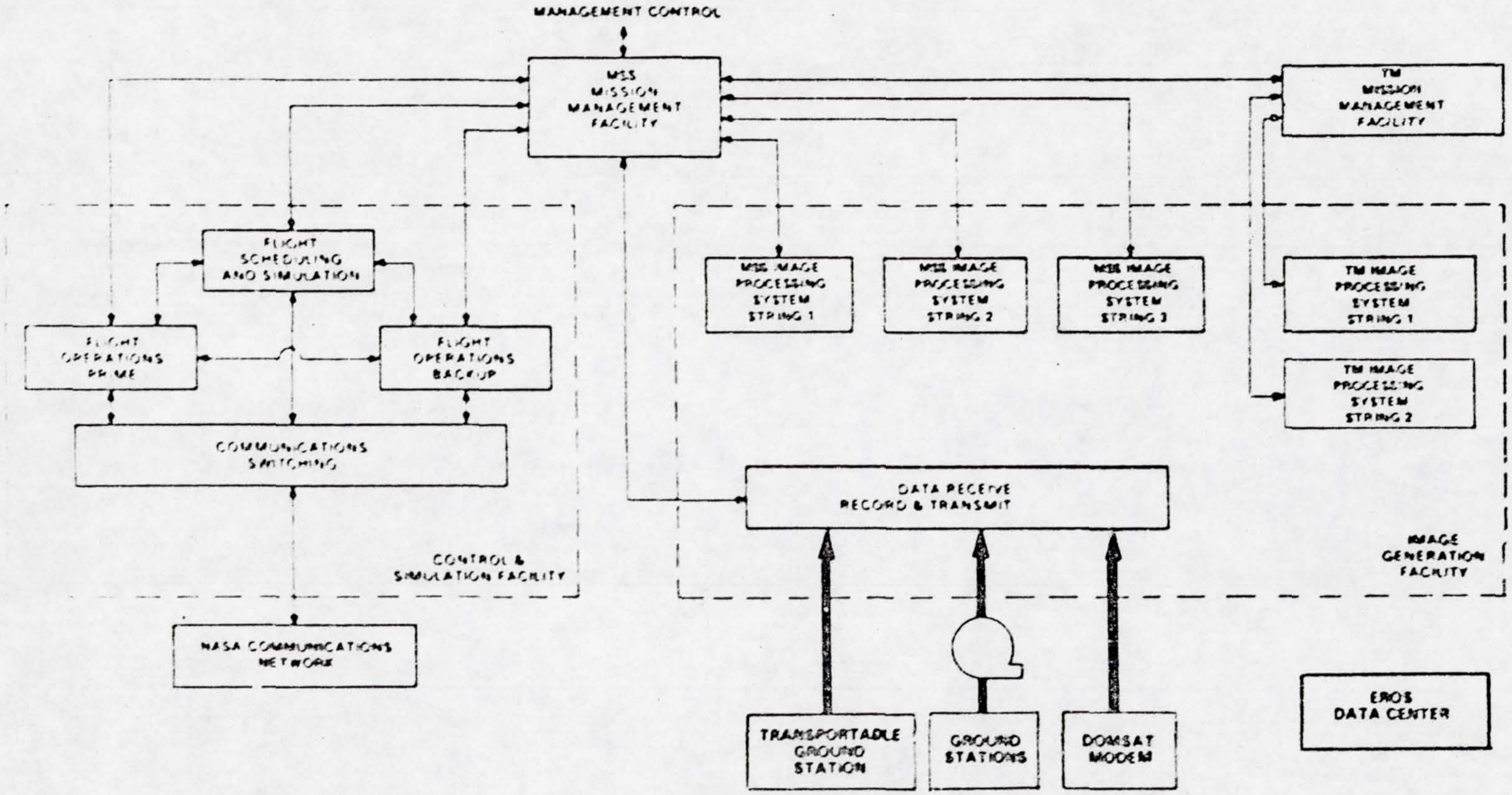
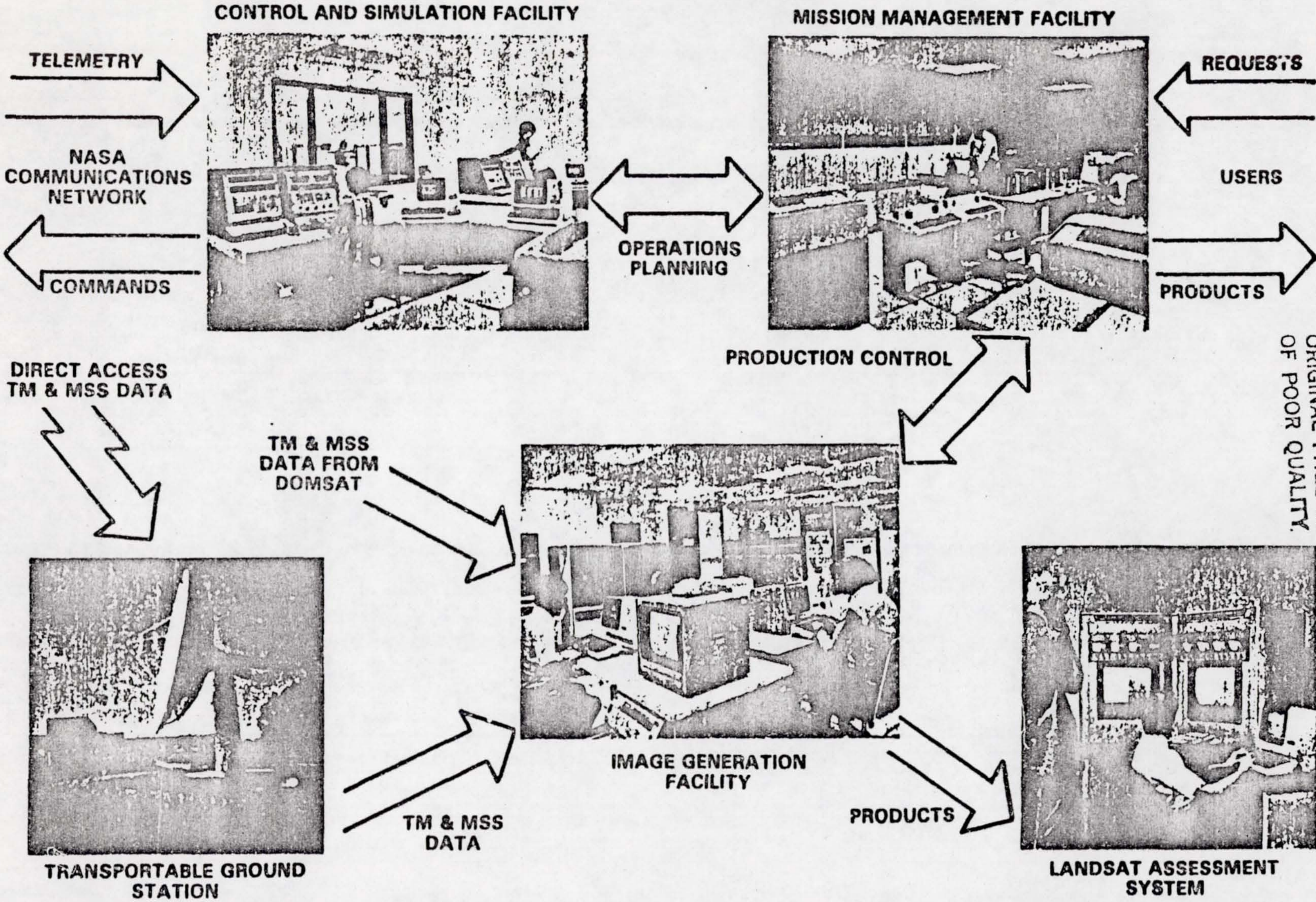
LANDSAT-D GROUND SEGMENT



LANDSAT D
GROUND SEGMENT



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Mission Management Facility Major Functions

- **Data Acquisition**
  - **PROCESS REQUESTS** for Data Acquisition
  - **PROVIDE CANDIDATE** Scene Data **ACQUISITION LISTS** for Satellite Operations Planning and Scheduling
  - **ACCOUNT FOR TELEMETRY** Data Acquisition
  - **ACCOUNT FOR IMAGE** Data Acquisition
- **Data Archive**
  - **SCHEDULE** Archival Processing
  - **MAINTAIN** Archival **DATA BASE** and Produce Image Catalogs
- **Product Generation**
  - **PROCESS REQUESTS** for Product Generation
  - **SCHEDULE** Product Generation
- **Ground Segment Management**
  - Maintain Ground Segment **SUPPLIES INVENTORY**
  - **TRACK** Ground Segment **PROBLEMS**
  - Provide **VERIFICATION AND SELF TEST** Capability
  - Provide **MANAGEMENT REPORTS**

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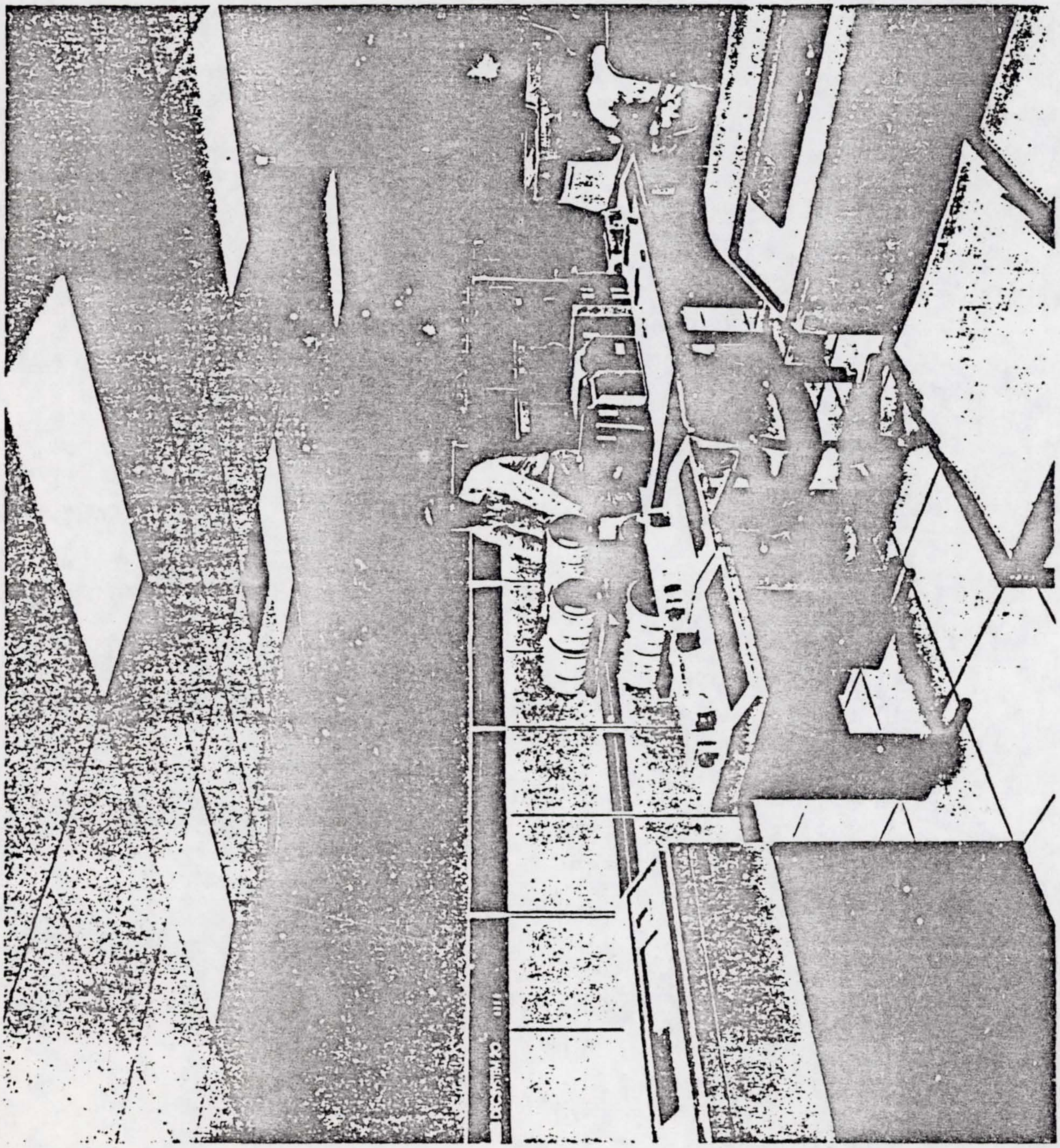


IMAGE GENERATION FACILITY

- DATA RECEIVE, RECORD TRANSMIT SYSTEM
- MSS IMAGE PROCESSING SYSTEM
- TM IMAGE PROCESSING SYSTEM

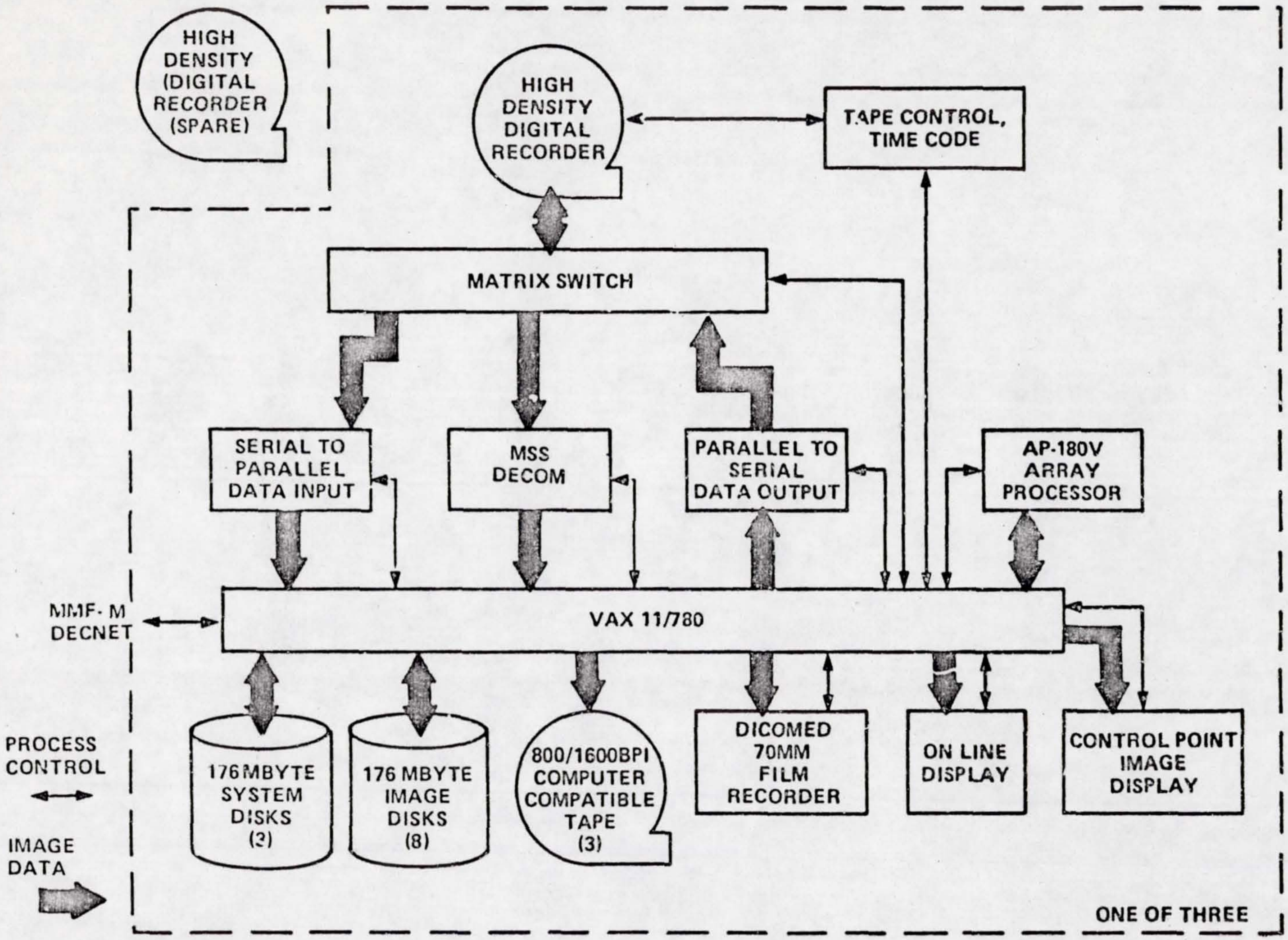
DATA RECEIVE, RECORD, TRANSMIT SYSTEM MAJOR FUNCTIONS

- RECORD MSS AND TM DATA
- GENERATE TAPE DIRECTORIES
- COPY HIGH DENSITY TAPES
- ARCHIVE HIGH DENSITY TAPES
- TRANSMIT MSS DATA TO EROS DATA CENTER

MSS IMAGE PROCESSING SYSTEM MAJOR FUNCTIONS

- PROCESS IMAGE RELATED TELEMETRY (ATTITUDE AND EPHEMERIS)
- GENERATE 28–TRACK ARCHIVAL TAPES
  - RADIOMETRICALLY CORRECTED
  - GEOMETRIC CORRECTIONS APPENDED
- CREATE QUALITY ASSURANCE PRODUCTS
  - COMPUTER COMPATIBLE TAPES
  - REPORTS
  - FULLY CORRECTED HIGH RESOLUTION FILM

MSS IMAGE PROCESSING SYSTEM HARDWARE



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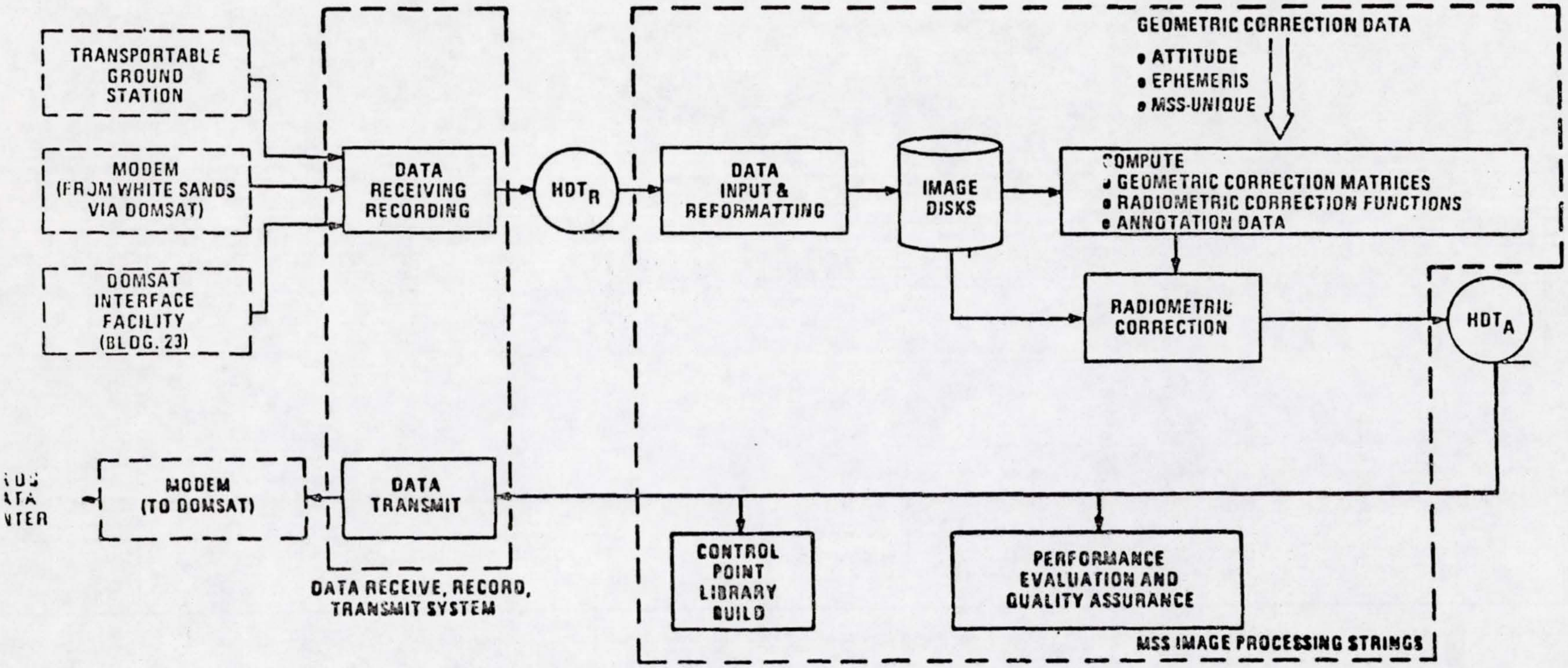
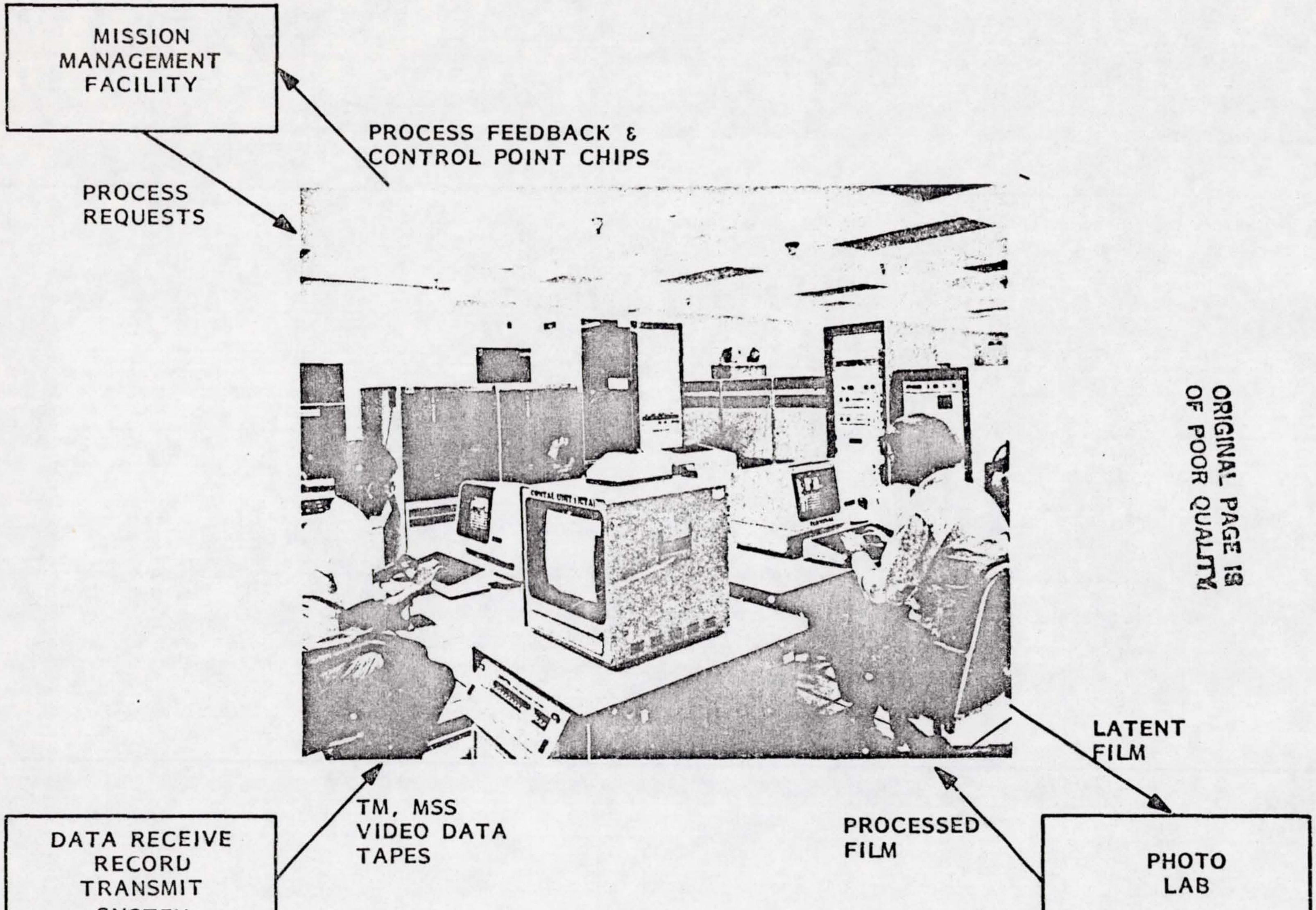
MULTISPECTRAL SCANNER
IMAGE GENERATION PROCESS FLOW



MSS IMAGE PROCESSING SYSTEM INTERFACES



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TM IMAGE PROCESSING SYSTEM
MAJOR FUNCTIONS

- PROCESS IMAGE RELATED CORRECTION DATA
  - GYRO
  - ANGULAR DISPLACEMENT SENSOR
  - MIRROR SCAN CORRECTION
  - EPHEMERIS
- GENERATE 28-TRACK ARCHIVAL TAPES
  - RADIOMETRICALLY CORRECTED
  - GEOMETRIC CORRECTIONS APPENDED
- GENERATE 28-TRACK FULLY CORRECTED TAPE
- GENERATE HIGH RESOLUTION FILM AND COMPUTER COMPATIBLE TAPE PRODUCTS
- CREATE QUALITY ASSURANCE REPORTS

TM IMAGE PROCESSING SYSTEM HARDWARE

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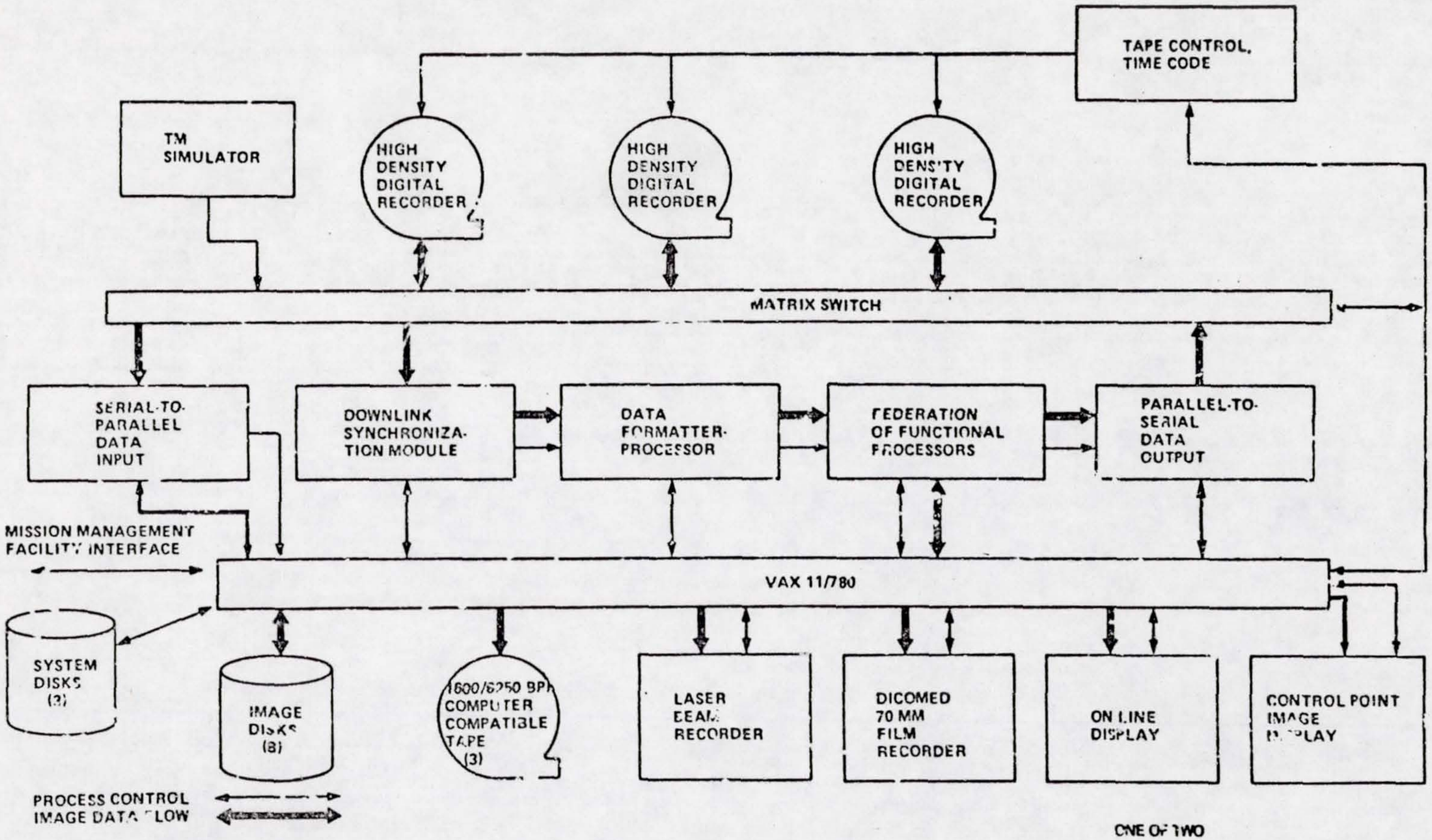
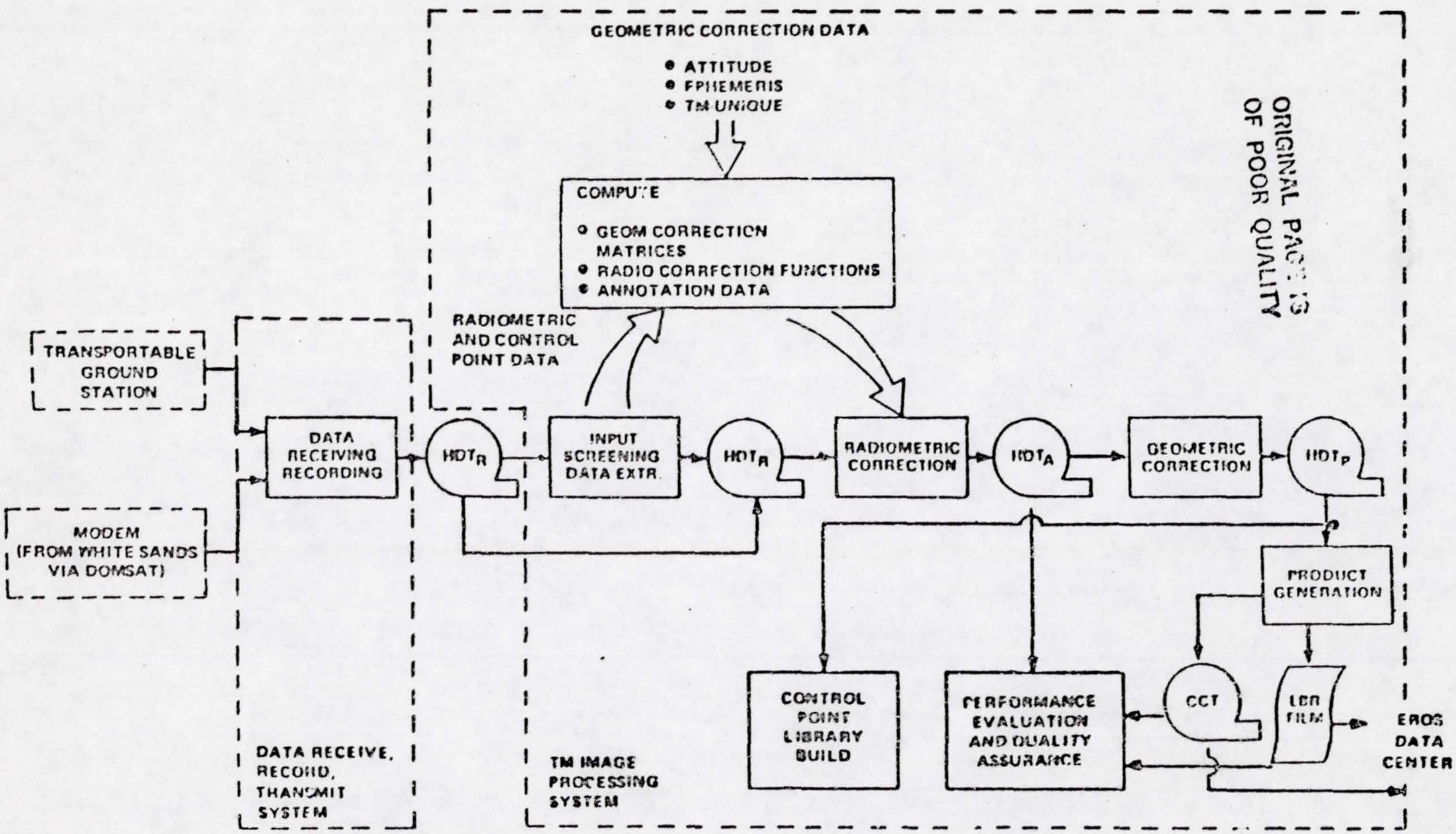
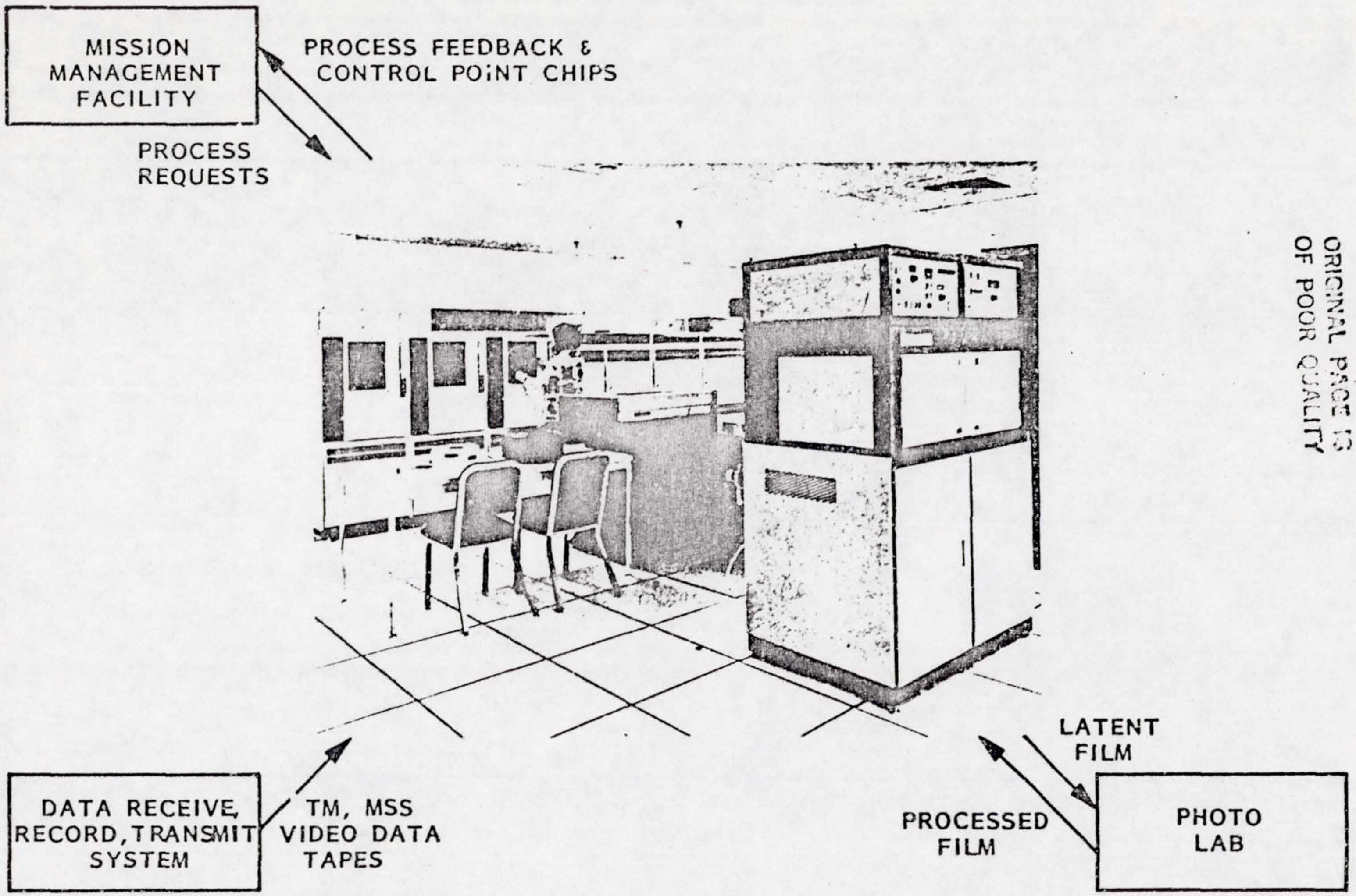


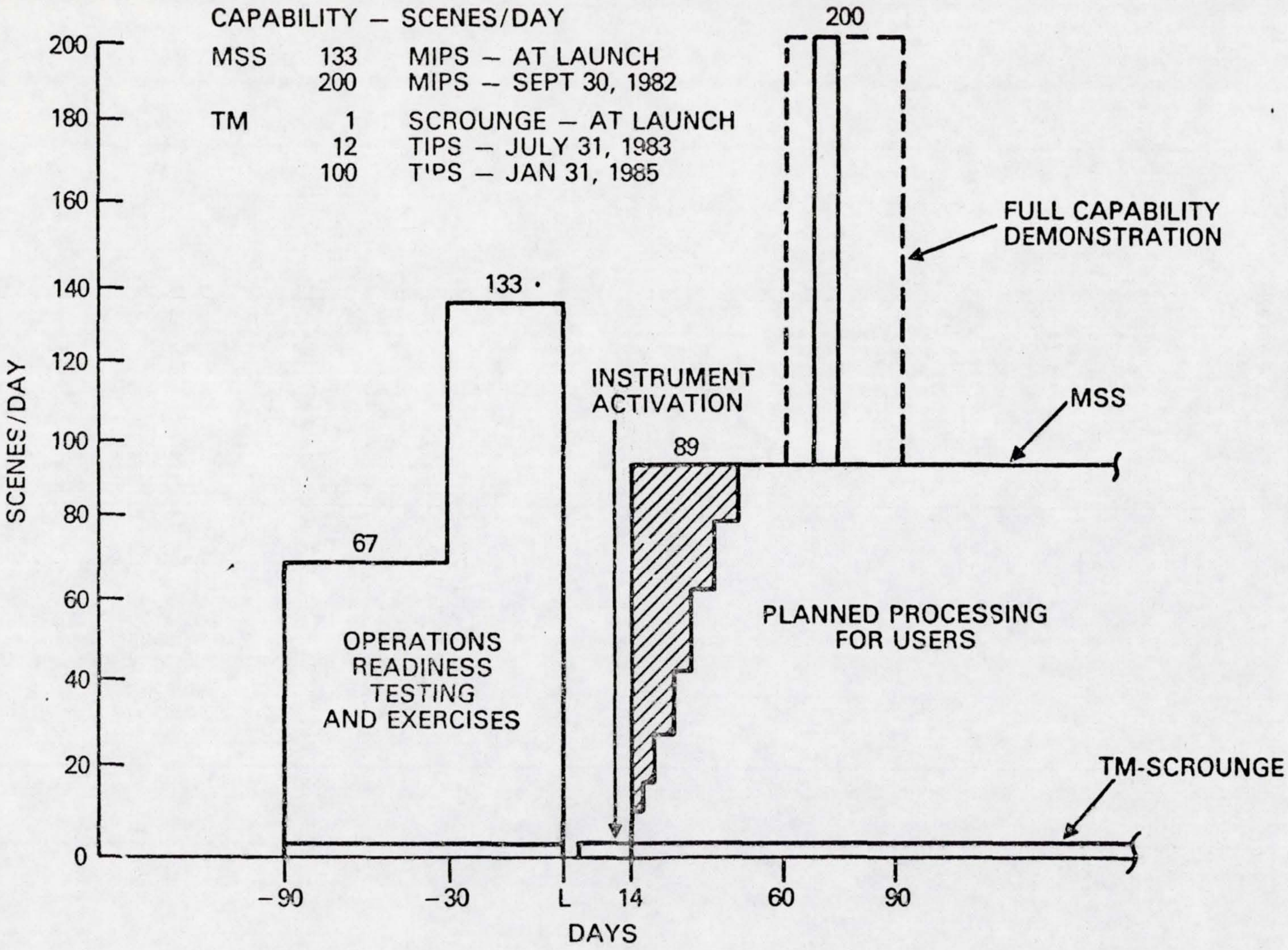
THEMATIC MAPPER IMAGE GENERATION PROCESS FLOW



TM IMAGE PROCESSING SYSTEM INTERFACES



Processing



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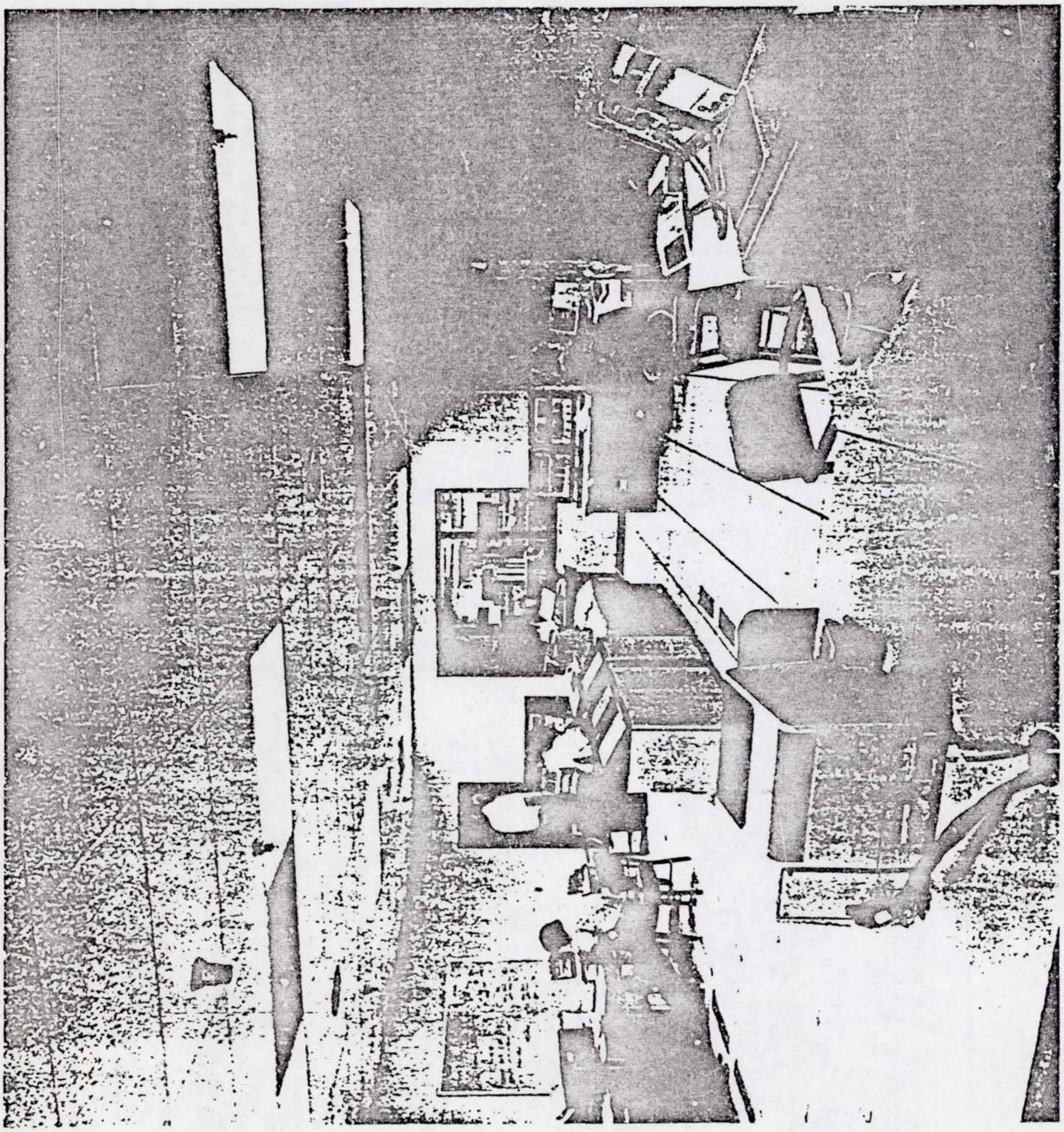
CONTROL AND SIMULATION FACILITY MAJOR FUNCTIONS

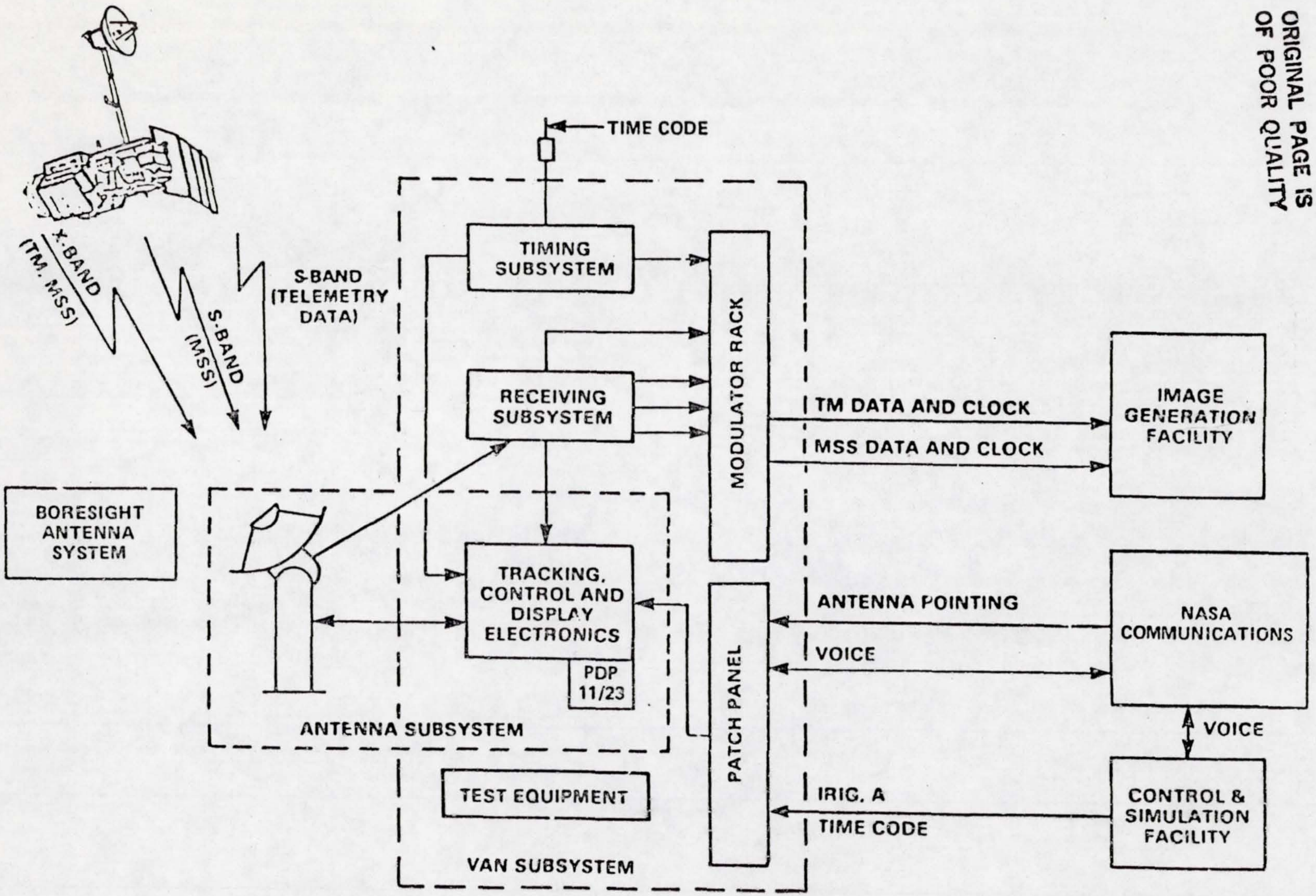
- PLAN AND SCHEDULE FLIGHT SEGMENT OPERATIONS
- SCHEDULE LINK SUPPORT WITH NETWORK CONTROL CENTER
- COMMAND FLIGHT SEGMENT
- ACQUIRE FLIGHT SEGMENT TELEMETRY
- MONITOR, EVALUATE, AND REPORT FLIGHT SEGMENT PERFORMANCE
- SIMULATE FLIGHT SEGMENT OPERATION
- REPROGRAM ON BOARD COMPUTER
- PERFORM SELF TEST



TRANSPORTABLE GROUND SYSTEM MAJOR FUNCTIONS

- ACQUIRE TM/MSS VIDEO DATA
  - OPERATIONALLY IN PRE-TDRSS ERA
  - SUPPORT EVALUATION IN POST-TDRSS ERA
- PROVIDE TM/MSS VIDEO DATA TO THE IMAGE GENERATION FACILITY
- PROVIDE CAPABILITY TO RECEIVE NARROWBAND TELEMETRY

TRANSPORTABLE GROUND STATION



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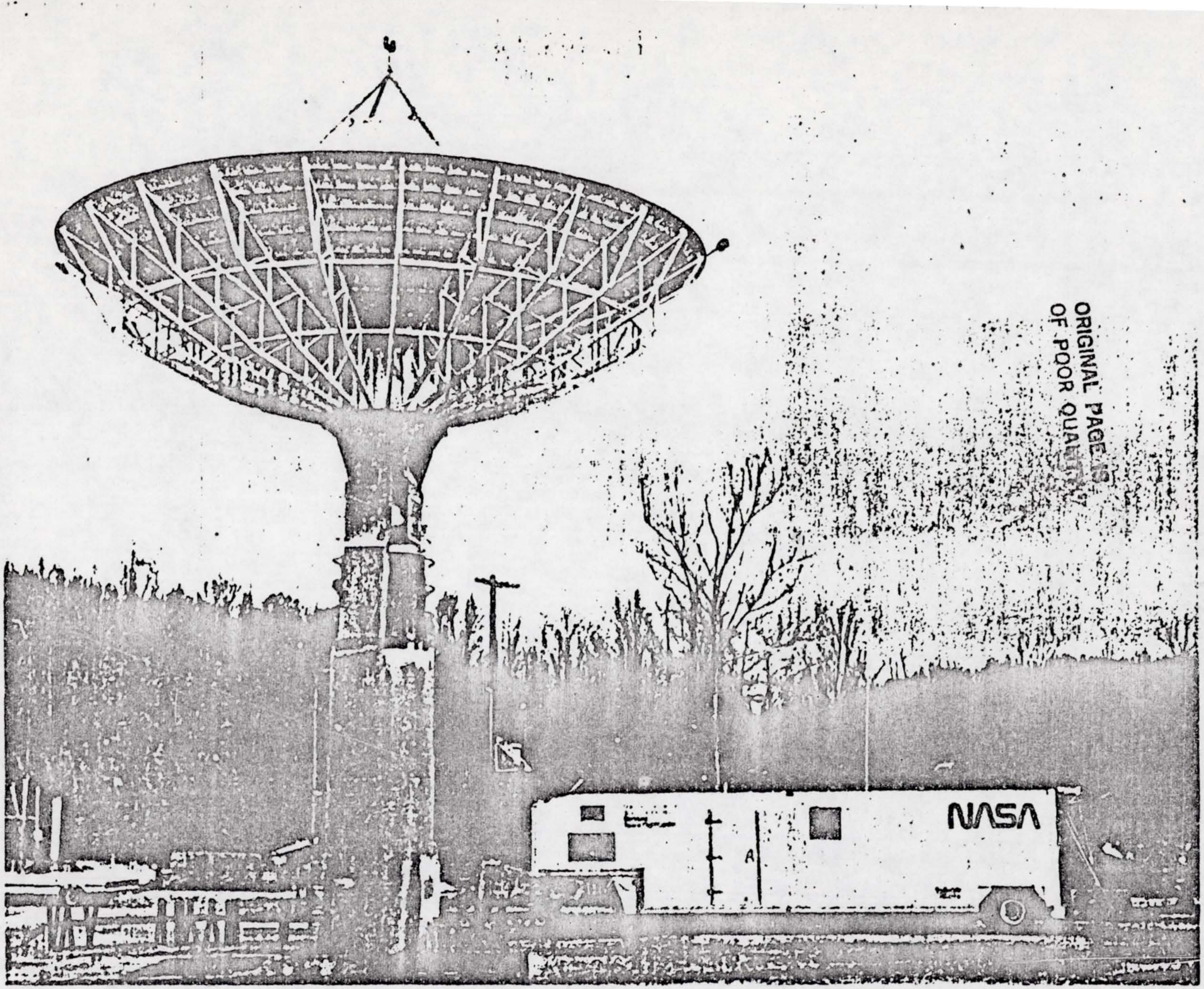
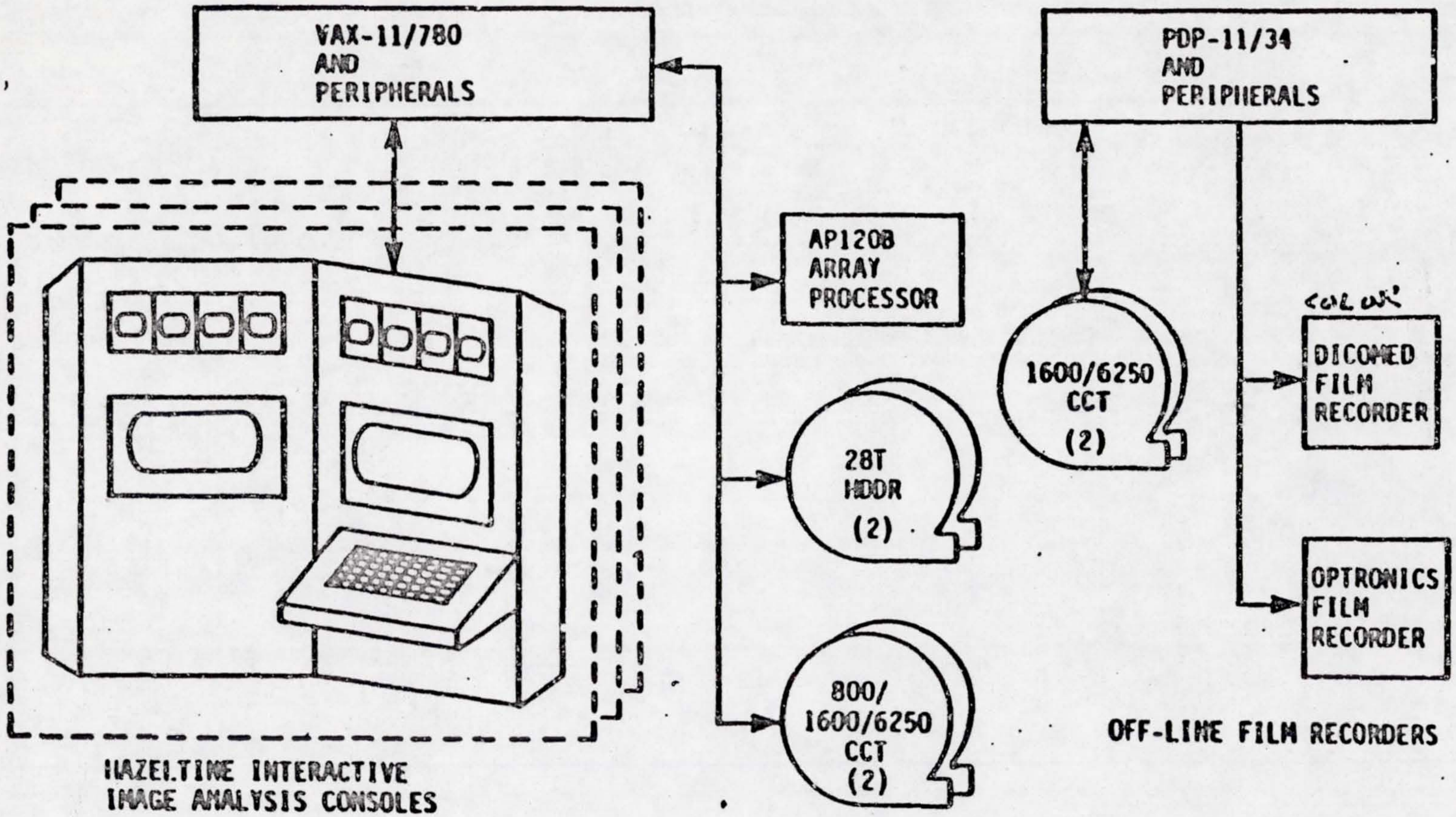

NASA

LANDSAT ASSESSMENT SYSTEM
MAJOR FUNCTIONS

- PERFORM DATA QUALITY AND IMAGE SCIENCE TESTS OF TM AND MSS
- COMPARE TM AND MSS SENSORS
- COMPARE LANDSAT-D TO PREVIOUS LANDSAT MISSIONS
- PERFORM LIMITED APPLICATIONS INVESTIGATIONS IN SELECTED DISCIPLINES

LANDSAT ASSESSMENT SYSTEM

HARDWARE OVERVIEW



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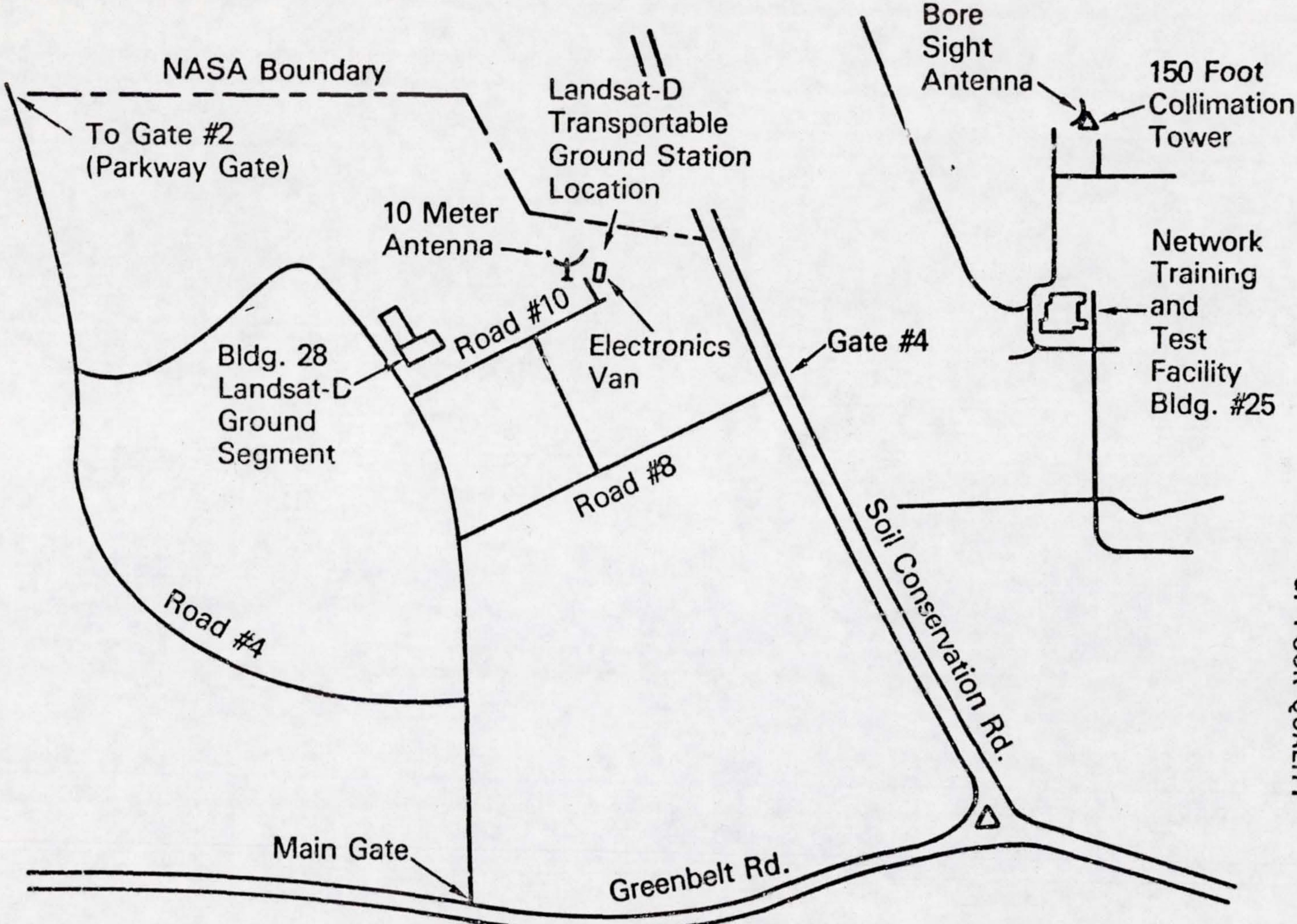
Landsat-D Ground Segment Location



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Landsat-D Performance Characterization

John Barker

Landsat-D Performance Characterization Activities

- Introduction
- Objectives
- Structure
- Engineering Verification
- Science Characterization
- Activities Schedule
- Investigations Workshop

Introduction

Landsat-D Performance Characterization is a Cooperative, Two-Part Engineering and Scientific Analysis Effort Designed to Foster the Effective Accomplishment of Overall Project Goals.

- Thematic Mapper (TM) Capability Assessment
- Multispectral Scanner (MSS) to TM Transition
- Operational System Feasibility Demonstration
- Continuity of MSS Imagery
- Continued Foreign Access

Objectives

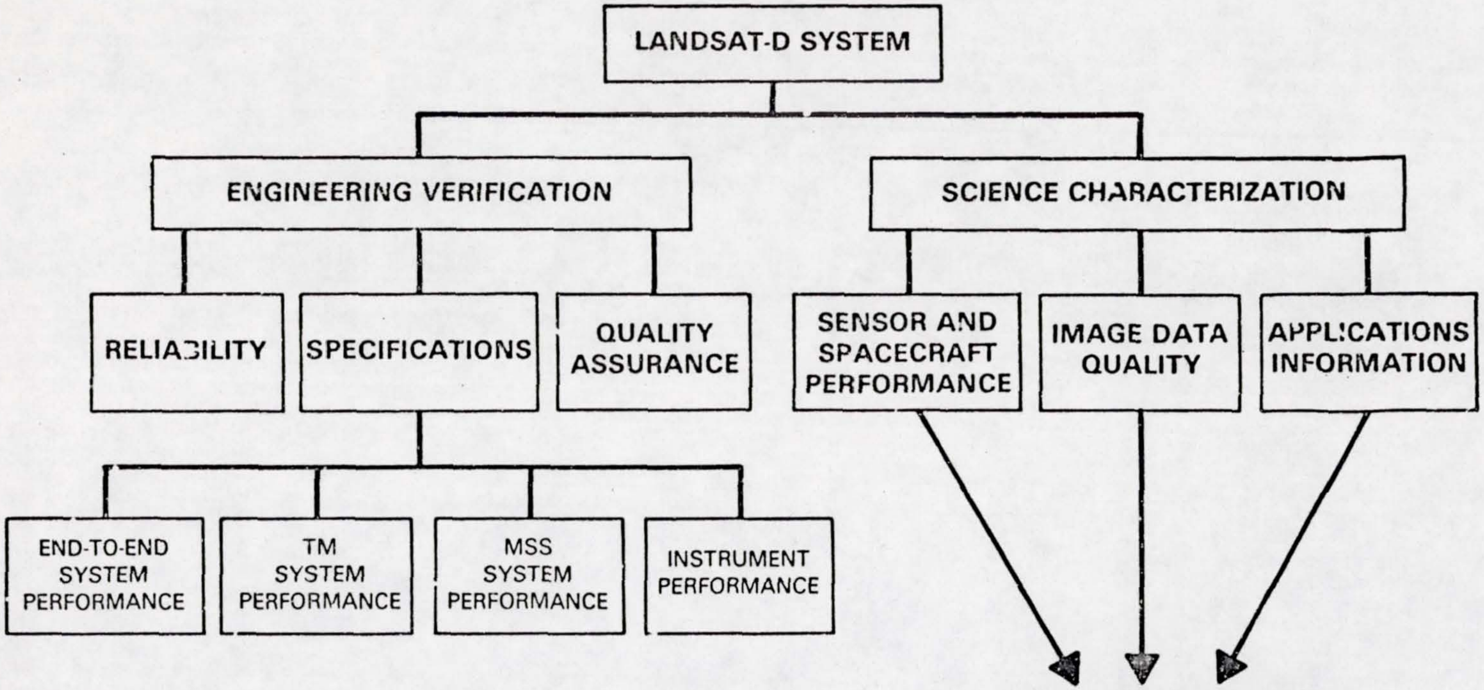
ENGINEERING:

- Verify Instrument, Data Processing Facility and Total System Performance to Specifications
- Establish Equipment and Operations Reliability
- Verify Product Quality Standards

SCIENCE:

- Characterize Accuracy and Precision of Sensor and Spacecraft Performance
- Characterize Accuracy and Precision of Image Data Quality
- Characterize Accuracy and Precision of Derived Information
- Recommend Landsat-D System Improvements
- Communicate Results to Research Community

Structure



- Recommend Landsat-D System Improvements
- Communicate Results to Research Community

Engineering Verification

Engineering Verification Organization

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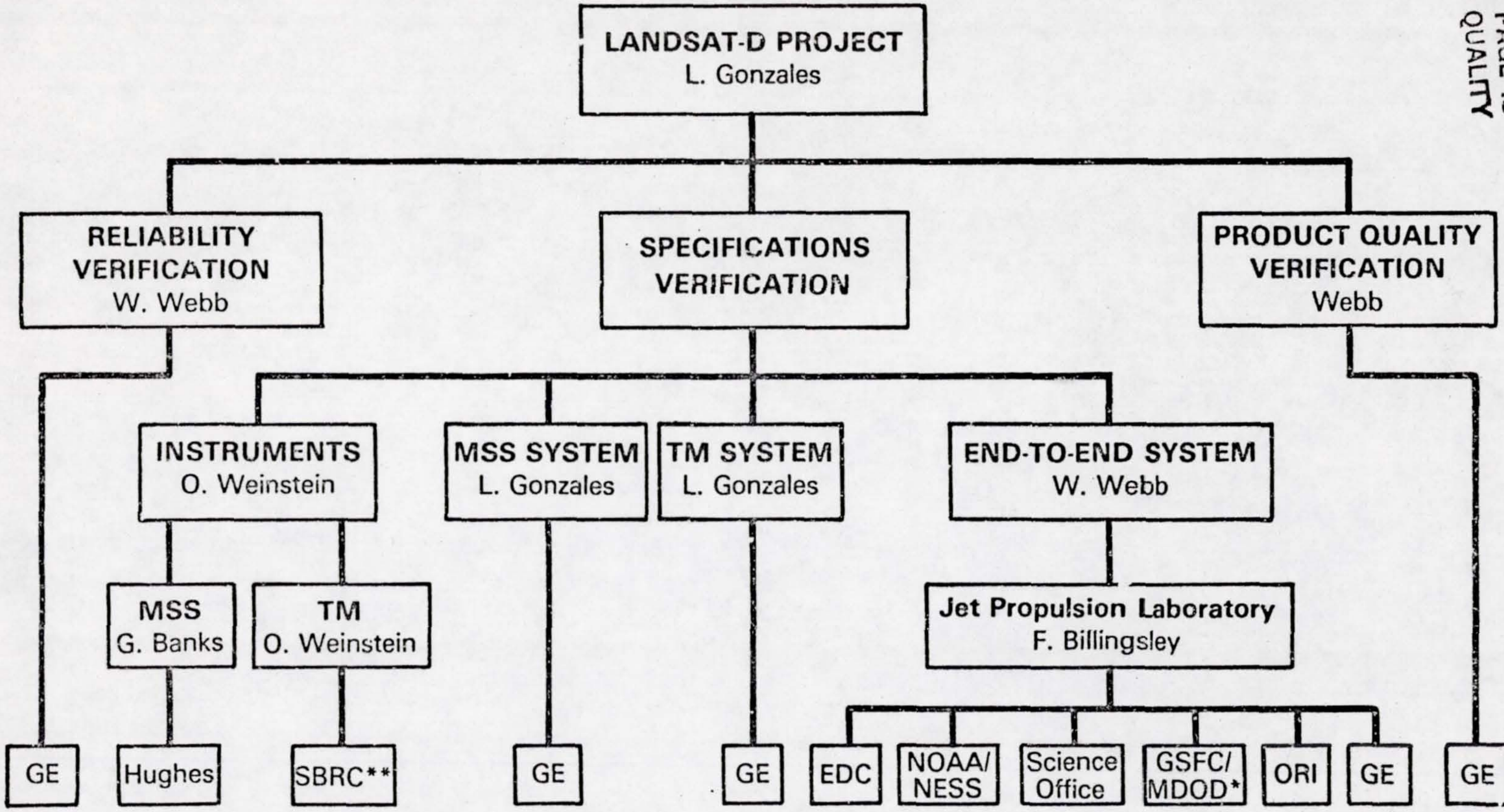
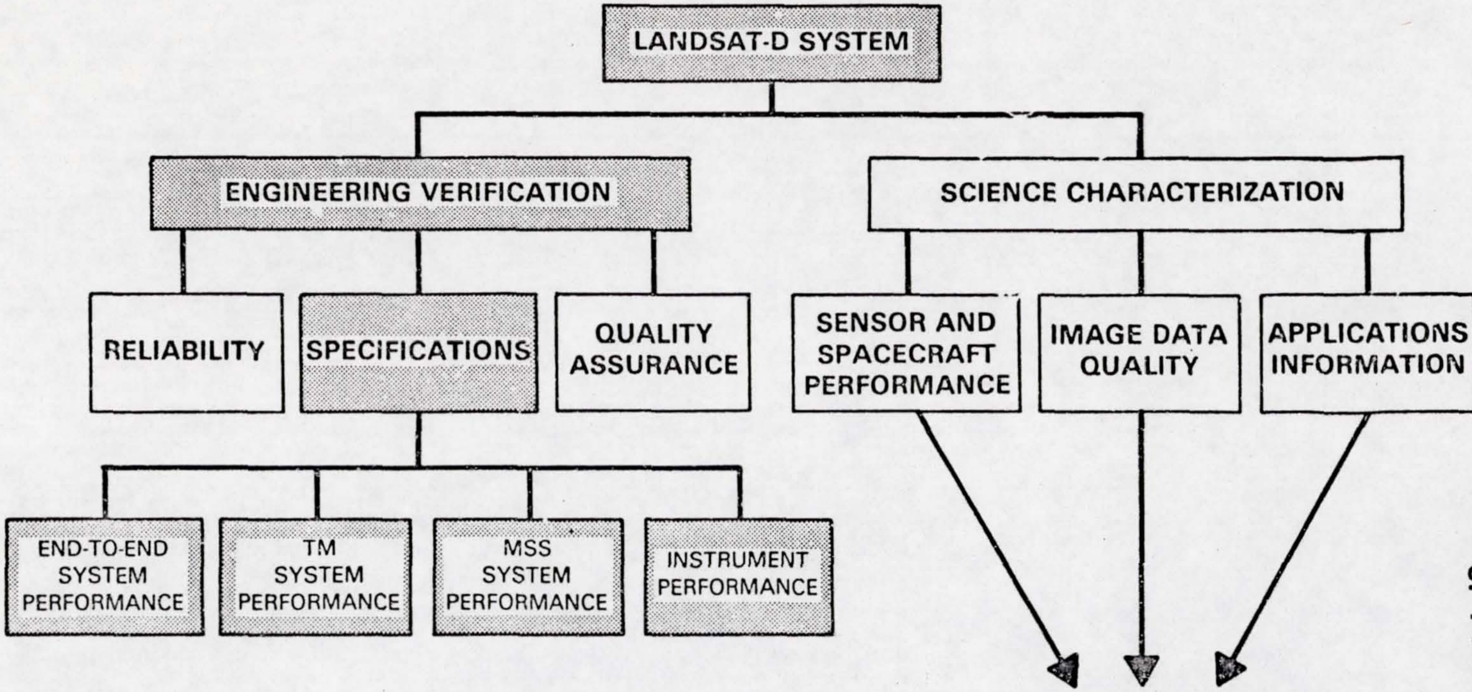


* MDOD Mission and Data Operations Directorate
** SBRC Santa Barbara Research Center

Structure



- Recommend Landsat-D System Improvements
- Communicate Results to Research Community

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Instrument Performance Analysis

(SENSOR SYSTEM LEVEL TESTS)

RESPONSIBILITIES	REPORTS
MSS-Protoflight and Flight (PF and F) Hughes	• Technical Memos • Pre-Ship Review • Final Report
TM (PF and F) Santa Barbara Research Center (SBRC)	• Technical memos • Pre-Ship Review • Post-Launch Support

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MSS and TM System Performance Analysis

GE RESPONSIBILITIES	REPORTS
Pre-Launch	
TM Radiometric Testing and Data Reduction	• Technical Memos
TM Geometric Testing	• Pre-Ship Review • Processing White Papers and Data Reduction
Post-Launch	
Radiometric Calibration and Validation Geometric Calibration and Validation	• Technical Memos • Post-Launch Support • Processing Parameter Update

End-to-End System Performance Analysis

RESPONSIBILITY

Fred Billingsley, JPL

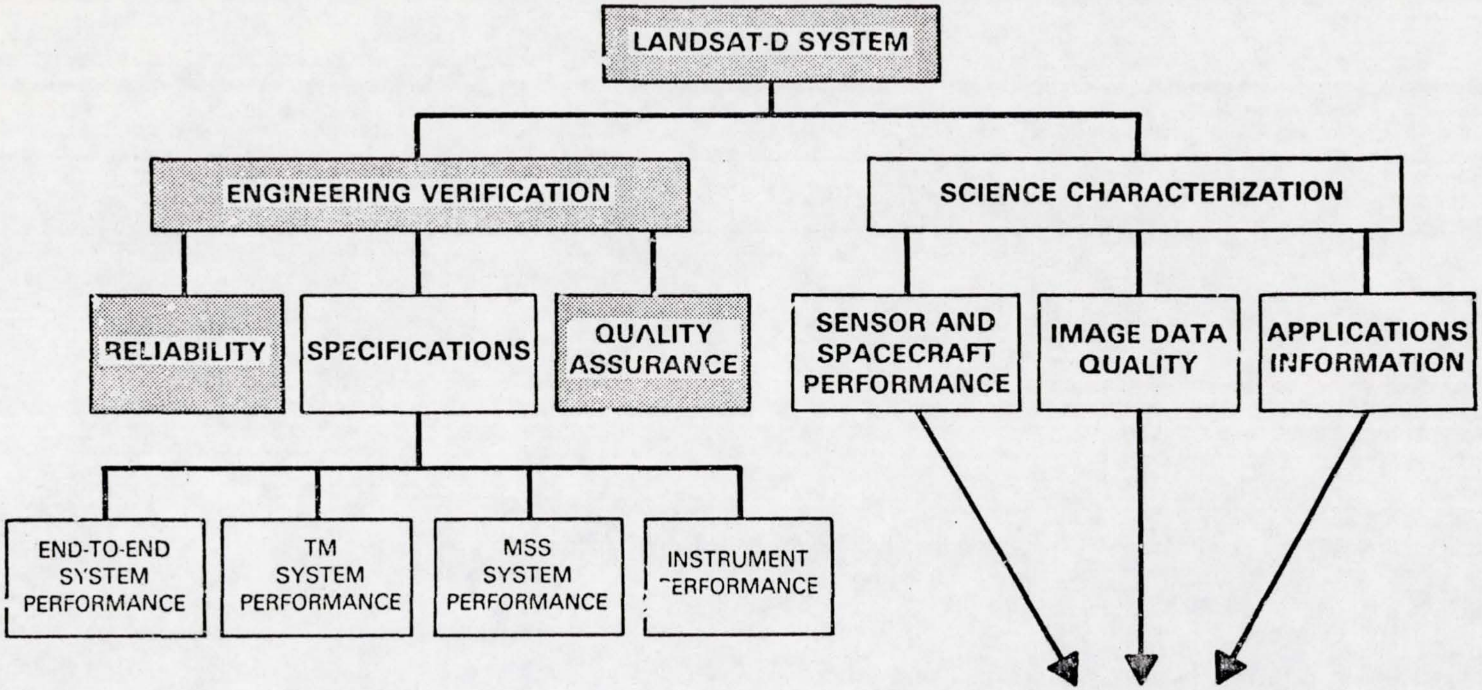
REPORTS

Pre-Launch Publication of **Landsat-D End-to-End System Performance Study**

STUDY OBJECTIVES

- Determine to What Extent Intended System Performance is Possible
- Estimate Image Technical Performance to be Expected
- Determine if Adequate Ancillary Information is Present
- Trace Effects of System Functions and Operations Through the System
  - Determine End-to-End System Operability
  - Estimate Cumulative Errors

Structure



- Recommend Landsat-D System Improvements
- Communicate Results to Research Community

Reliability Verification

RESPONSIBILITY (ONGOING)	REPORTS
GSFC Mission Operations Manager (Webb) GE Engineering Support Organization GE Quality Assurance Organization	Maintenance Plan Configuration Management Plan Equipment Service Reports (ESR) Problem Defect Reports (PDR) Management Reports • Utilization • Mean Time to Repair • Inventory and Supplies • Production Statistics • Maintenance Histories

Quality Assurance Verification

RESPONSIBILITY (ONGOING)	REPORTS
GSFC Mission Operations Manager (Webb)	
GE Quality Assurance Organization	
• Product Evaluation	Quality Assurance Reports Processing Summary Reports
• Process Evaluation	Automated PDR and ESR Management Reports System Audit Reports Special Management Reports (Trend Analyses & Current Quality Problem Daily Report)

Quality Verification Supporting Information

INFORMATION	SOURCE
• "Approaches to Satisfying Landsat Data User Concerns"	• The Operational Landsat-D Quality Assurance/ Performance Evaluation Plan Review Meeting, February 1982 (Final Report)
• Performance Evaluation Product Generation	• Landsat-D Mission Operations Review (MOR), April 6-7, 1982
• Operational Quality Assurance	• MOR, April 6-7, 1982

TABLE 1: APPROACHES TO SATISFYING LANDSAT DATA USER CONCERNS

USER CONCERNS	REQUIREMENTS	APPROACH TO SATISFYING REQUIREMENTS
TIMELINESS OF DATA:		
Throughput	• 200 New MSS Scenes/Day	• High Level of Back Up in Design
Turnaround Time	• 48 Hours from Receipt of Data	• Most Equipment Off-the-Shelf, Proven Performance • Availability/Reliability-Maintenance, Spares Philosophy • General Purpose System Simulator (GPSS) Model: - Timeliness, Utilization, - Failure Mode Effects Analysis, - Optimization of Operating Scenarios • Automatic Monitoring, Reporting of Performance
COMPLETENESS OF DATA:		
Treatment of Data Dropouts, Errors	• Replace Lost Data with Last Good Data • Detect and Correct Bad Time Codes • Report All Substitutions on Digital Products	• Request Retransmission of Bad Data Transfers from White Sands • Provision to Skip Bad Data on Scene Basis • Repetition of Last Good Video Data for Lost Video Line • Insertion of Flywheel Times for Bad Time Code • Automatic Reporting of Substitute Video Data in Line Quality Maps
RADIOMETRIC QUALITY OF DATA:		
Absolute and Relative	• ±1 Quantum Level over Entire Detector Range (6 Bit Data) within each Band	• Calibration on Wedge for Absolute and Band-to-Band Fidelity • Nominal Calibration Wedge for Back-Up • Scene Content for Detector-to-

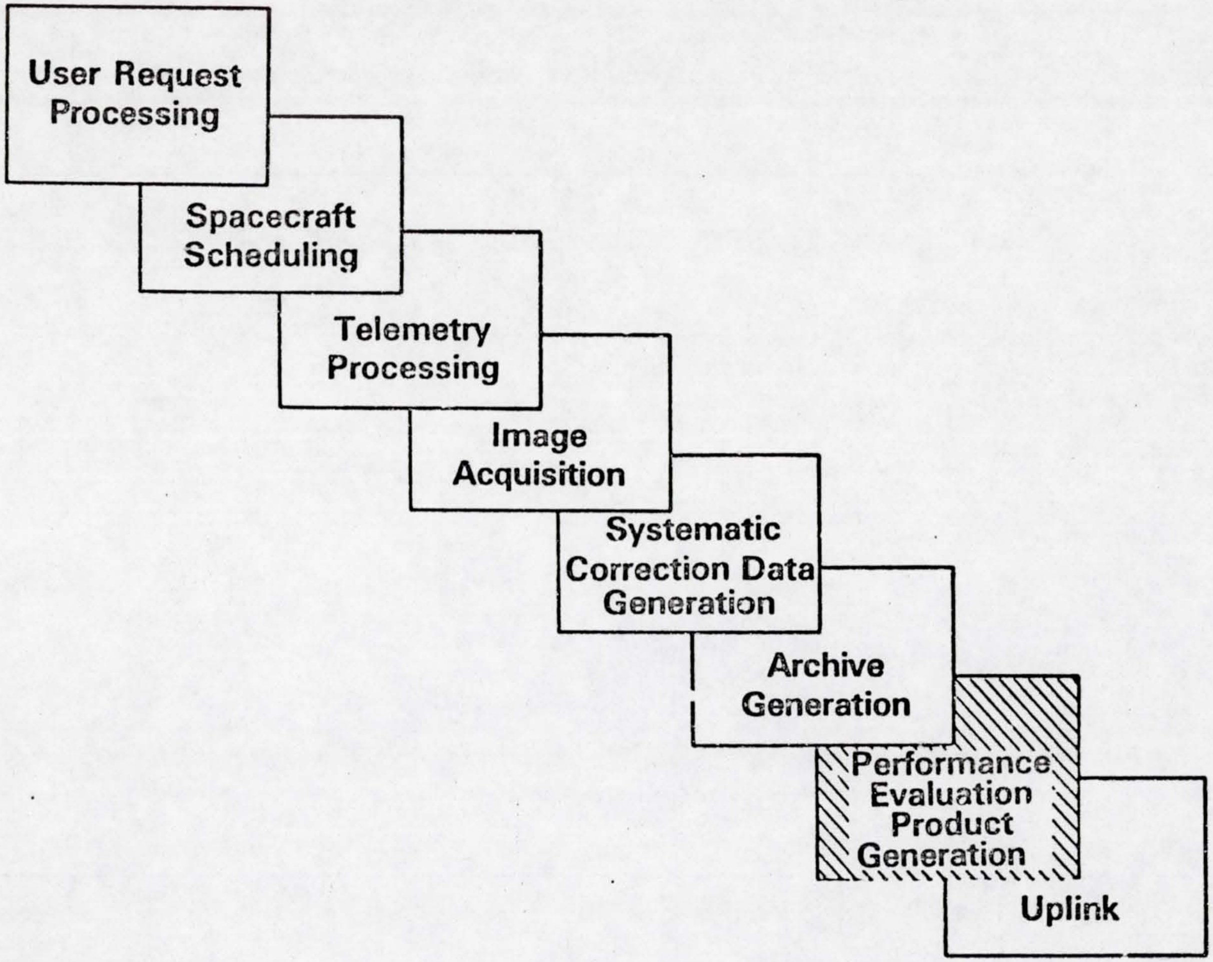
TABLE 1: APPROACHES TO SATISFYING LANDSAT DATA USER CONCERNS (Cont'd)

USER CONCERNS	REQUIREMENTS	APPROACH TO SATISFYING REQUIREMENTS
RADIOMETRIC QUALITY OF DATA (Cont'd):		Detector Ranging (Destriping) • Techniques Demonstrated on LS-2 Data: - Meet ±1 Quantum Level Detector Range - Means and Variances of Radiance Population Preserved for each Sweep • Automated Assessment of Performance Part of Processing System
GEOMETRIC QUALITY OF DATA:		
Absolute and Temporal	• 0.3 Pixel Temporal Registration Accuracy (90%) • 0.5 Pixel Geodetic Accuracy (90%)	• Systematic Correction Data (SCD): - Models of Spacecraft/Sensor/ Earth System - Ephemeris, Attitude Measurements - Residuals Include Measurement Errors, Unmeasured Attitude Components (All Frequencies), Scanner Alignment, Scan Repeatability • Geodetic or Temporal Correction Data (GCD): - From Automatic Control Point/ Control Point Neighborhood (CPN) Registration (After Systematic Correction of CPN) - Techniques for Detecting False Correlations - Filtering of Systematic Control Point (CP) Location Errors to Update SCD to GCD
AVAILABILITY OF DATA QUALITY MEASURES:	• Daily and Continuing Readiness for Operations (Quality Assessment)	• Quality Measures for All Phases of Processing

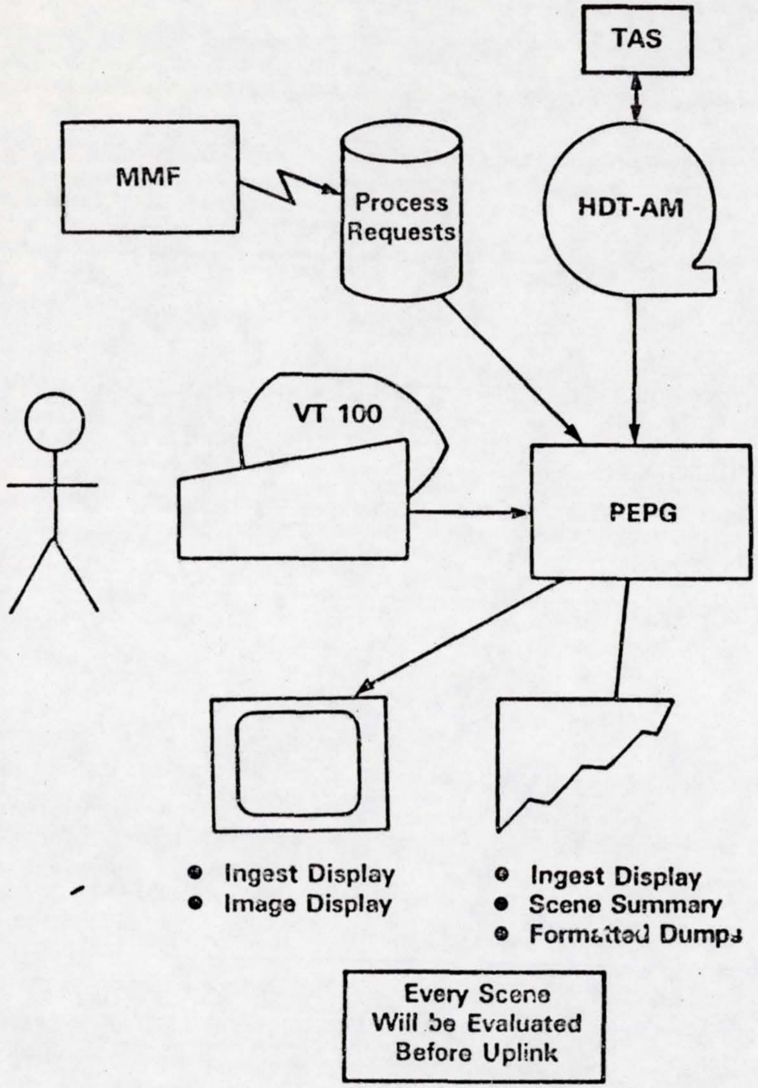
TABLE 1: APPROACHES TO SATISFYING LANDSAT DATA USER CONCERNS (Cont'd)

USER CONCERNS	REQUIREMENTS	APPROACH TO SATISFYING REQUIREMENTS
AVAILABILITY OF DATA QUALITY MEASURES (Cont'd):	• Assurance Quality of Products • Evaluation and Enhancement of Performance	• Some Quality Measures Evaluated Against Thresholds to Determine: - Rework - Rejection • Long Term Evaluation and Enhancement of System

Standard MSS Processing



PEPG—HDT-AM Evaluation



- Input Source/Process Request
- How/Manual Selection Via Menu for Automatic Processing
- Who/Computer Operator Using Standard Procedures
- Where/Any MIPS String

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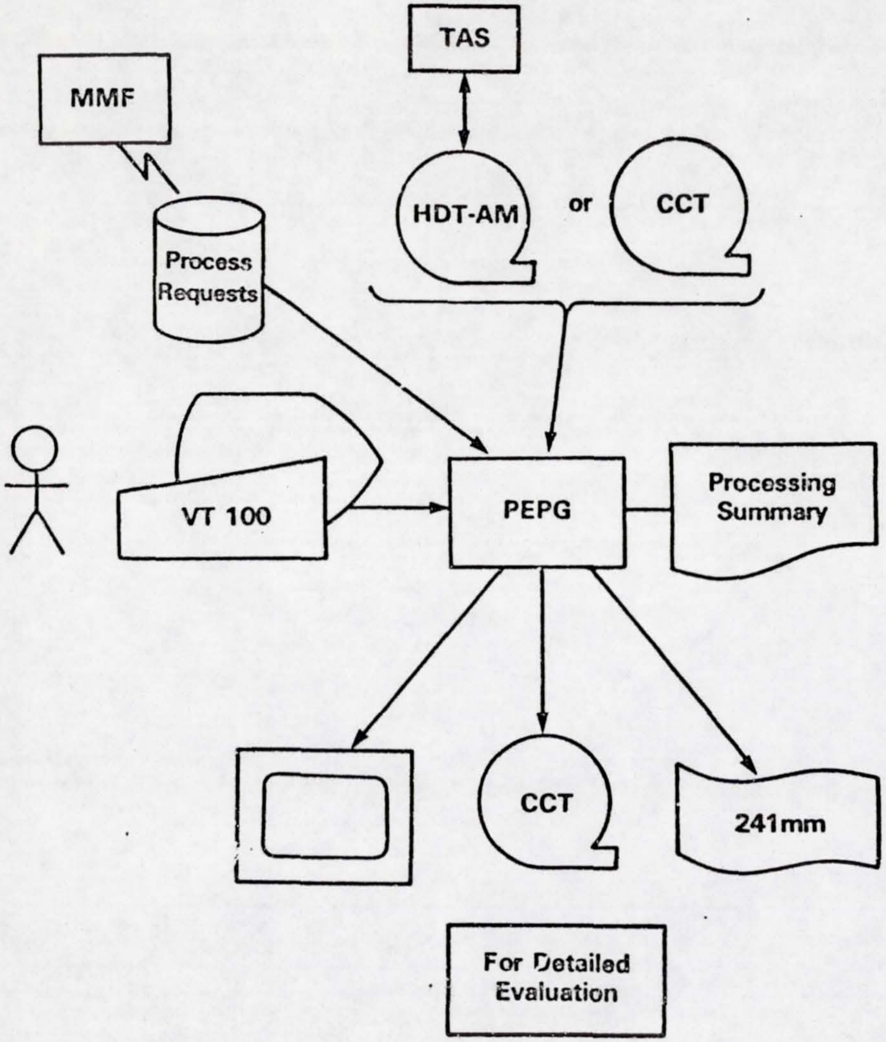
HDT-AM Evaluation—Sequence of Events

- Display Available Work
- Start Product Evaluation
- Operator Prompted for:
  - HDT-AM Mount
  - HDT-AM Dismount
- Ingest and Scene Summary Reports Generated Automatically
- Selected Scenes Stored on Disk for Evaluation by Quality Assurance
  - Formatted Dumps
  - Image Display

PEPG Product Generation

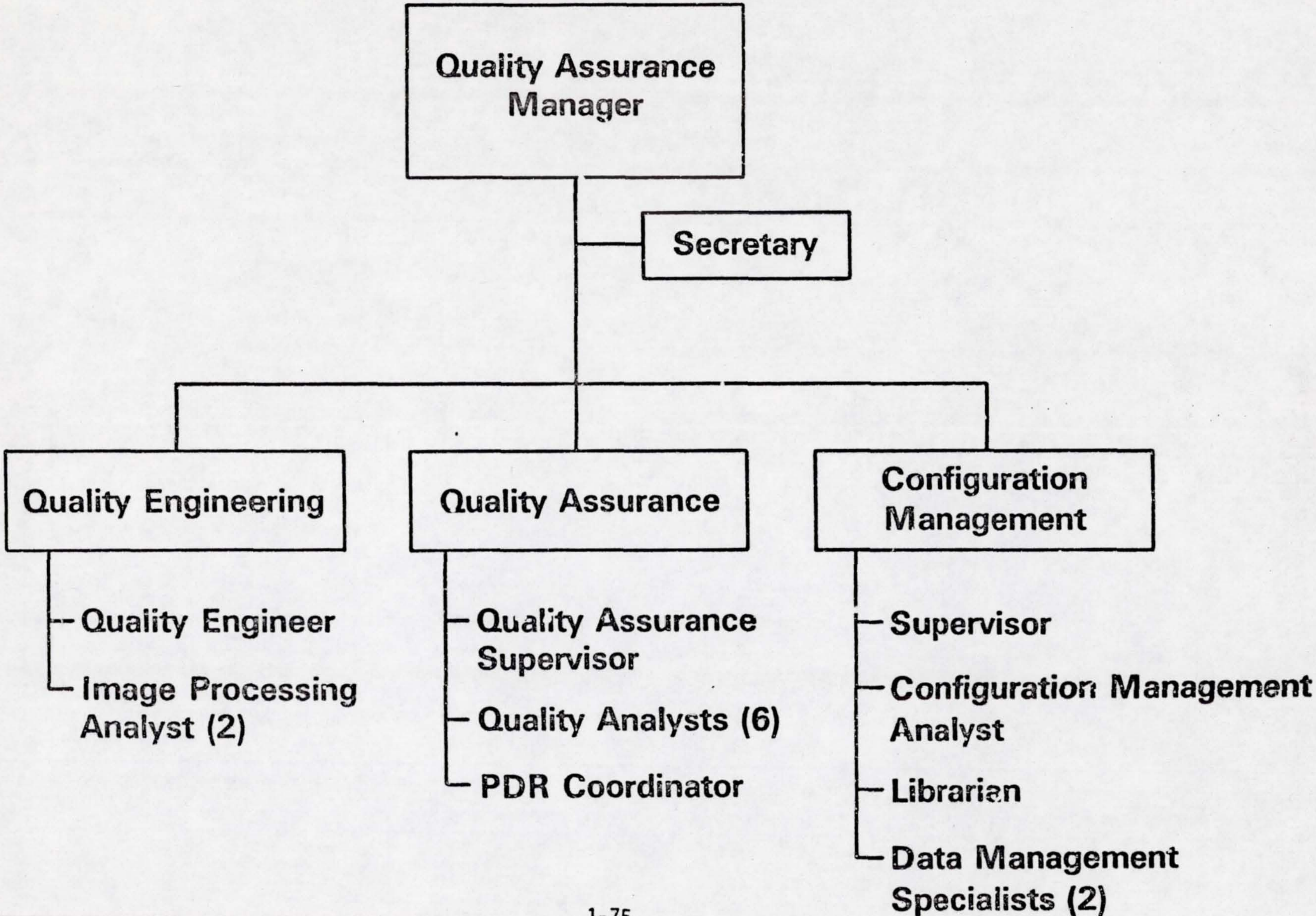


Input Source/Process Request

- How/Manual Selection Via Menu for Automatic Processing
- Who/Computer Operator Using Standard Procedures
- Where/MIPS for CCT (2 Scenes/Day) TIPS for 241 mm (9 Scenes/Day)

Operational Quality Assurance

Quality Assurance Organization



Quality Assurance—Responsibilities

<u>Assure Performance</u> — Measurement
— Evaluation
— Adjustment
— Enhancement

<u>Problem Management</u> — Prevention
— Detection
— Investigation
— Solution
— Reporting

Quality Assurance Implementation

- Quality Assurance Concepts
- Product Evaluation
- Process Evaluation

Quality Assurance Concepts

- Quality Assurance Features Designed Into System
- System is Fault Tolerant–Thruputs All Processable Data
- Fault Detection Built in, Limits Initially Set High
- System Captures Quality Indicators
  - — Stored in MMF Data Base
  - — Available in Many Computer Reports
- Quality Screening Responsibility Shared With Other Operators
- Quality Personnel Allocated for Problem Identification and Solution
  - — Supported by Automated PDR/ESR System
- High Visibility to Management of Problem and Quality Reports

System is Fault Tolerant

DRRTS

ECC's—Count Limit Checked   ≤10 Uncorrectable (MSS)   ≤1000 Correctable (TM)

— If Exceeded, Alarms for Operator; Summary in QA Report

Major Frame Sync Loss—If >10 Consecutive, Automatically Breaks Interval

Bad Time Code—Identified in Directory

—Operator Instructed Via SOP to Re-Dub Good Time Code Data

Recording Quality From TGS—Displayed in Moving Window Display (Read After Write)

—Operator Response

- Notify TGS if Transmission Bad
- Switch Recorders if Recorder Problem

MMF

Quality Checks ECC's and Sync Loss Against Limits—Limits Initially Same as DRRTS/MIPS

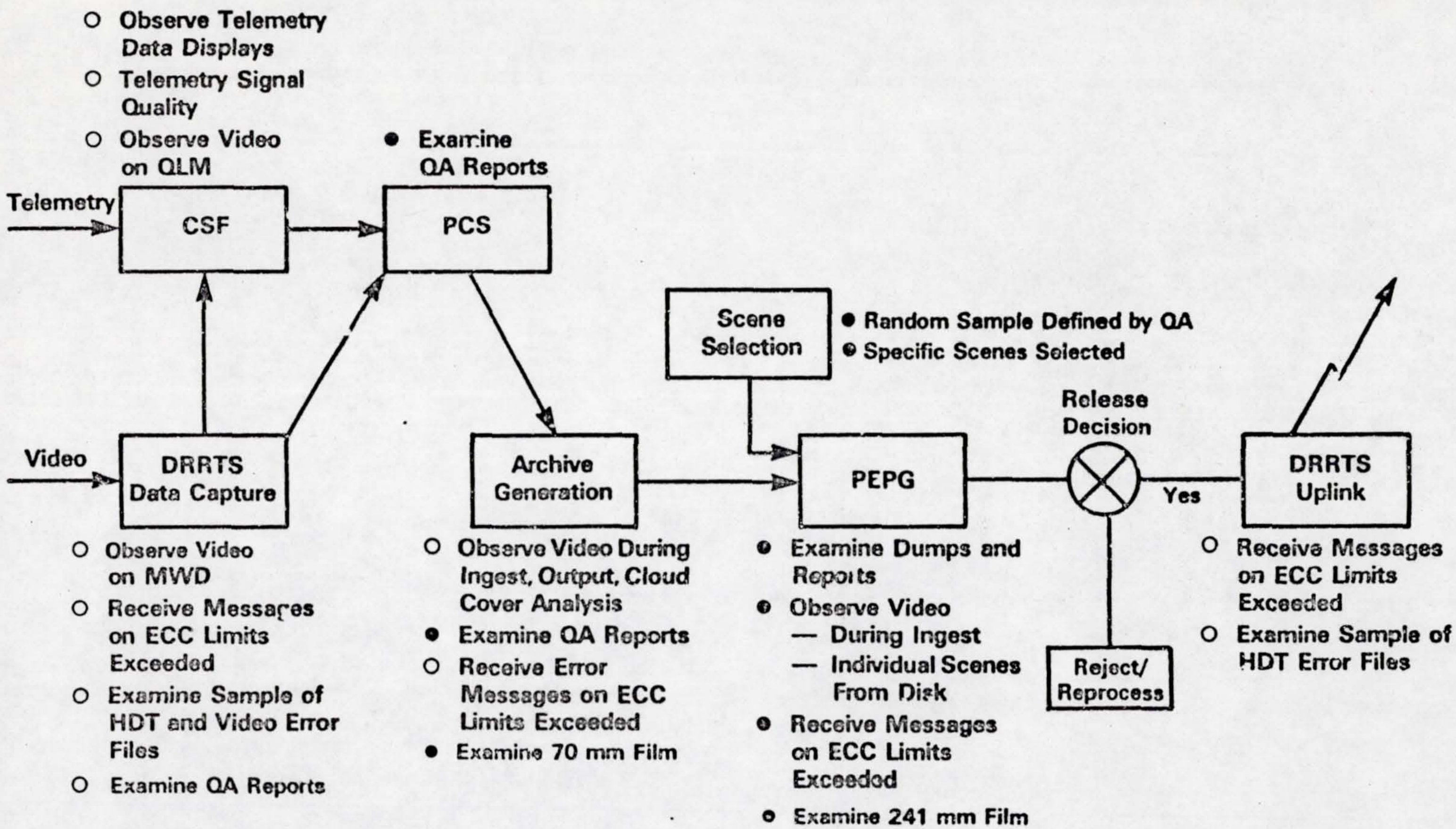
MIPS

ECC's—Same Alarms as DRRTS

Time Code—Substitutes if Can't Read

Sweep Substitution—Limit Checks—if Sync Loss for 10 Consective Major Frames, Declares Partial and Continues to Next Scene

QA Scenerio for Normal Processing (HDT-AM Generation)



QLM: Quick Look Monitor
MWD: Moving Window Display
ECC: Error Correcting Code

O — Performed by Operators
● — Performed by QA

Product Evaluation

Assess Image Quality

- Real Time by Quality Analysts Using Visual and Data Evaluation Techniques
- Real Time by CSF/DRRTS Operators Using Moving Window Display, Quick Look Monitor, and Evaluators Consoles
- Off Line by Image Processing Analysts Using Visual and Data Evaluation Techniques

Authorize Uplinking of Acceptable Products

- By Quality Analysts Following PEPG Process
- By Image Processing Analysts Following Detailed Evaluation of Rejected/ Reprocessed Data

Establish Accept/Reject/Reprocess Criteria

- By Image Processing Analysts With Concurrance of Engineering Review Board
- Update Using Pre and Post Launch Experience

Investigate User Feedback

- By Image Processing Analysts With Response Thru Project Office

Image Quality Assessment—Visual Techniques

- Each Scene—Scrolling Video Display (PEPG)

  <u>Evaluation Criteria</u>

  — Video Present

  — Anomalies in Video Data

  — Correlate Video Data With Operator Messages

- 1 Band/Scene to 70 mm Film Product

  <u>Evaluation Criteria</u>

  — Presence of All Characteristics (E. G., Video, Annotation, Tick Marks, Scene ID)

  — Anomalies in Video Data (Striping, Line Starts, Sync Loss)

  — Correlation With QA Reports

- PEPG —Upon Request by Image Processing Analyst

  — Detailed Evaluation Using Comtal Display and 241 mm Film

  — Typically Used for—

  - More Thorough Evaluation of Apparent Problems Observed During Process
  - Investigation of PDR's
  - Precise Measurements to Support Performance Analysis

Image Quality Assessment—Data Analysis Techniques

- Uses "Quality Indicators" Designed Into System
- Data Available From--

  Various Processing Reports

  Tape Annotation Records

  QA Reports

  MMF Quality Files

Quality Indicators Used Real Time

  Limit Checks in Software

  Correlate to Video Display During PEPG

  Accept/Reject/Reprocess Criteria Established in SOP's

  Annotate Products for Users

Used Off Line

  To Aid in Problem Investigation

  To Support Performance Trend Analysis

  To Support Adjustments in Criteria—Accept/Reject/Reprocess

  To Support Changes in S/W Limit Checks

Typical Quality Indicators

DRRTS — Image Quality Data File

Location DECNET Header Record (DRRTS ⟶ MMF)

Data — Major Frames Out of Sync
Minor Frame Sync Loss
Minor Frame Sync Bit Errors
Bit Slips

MAG QA Report — By Scene

Radiometric Quality — Detector Data
Summary by Band

MAG Processing Summary Report — By Scene

Band Quality Indicators — Derived From

Minor Frame Sync Loss
Major Frame Sync Loss
Line Substitutions
Missing Line Starts

Typical QA Report

Band Quality Indicators

Launch Baseline Criteria - All Quality Levels Acceptable
With Operating Experience - Acceptable Threshold May Be Fstablished

Acceptable Limit For Uncorrected - 10
Criteria given To QA For Uplink Decision

SCENE SUMMARY DATA

SCN NUM	NASA SCENE ID	INTERNAL SCENE ID	SCN STAT	A/D-QOS 1 2 3 4	HOT-AM ECC : UNCORR	CORR	HOT-RM ECC : UNCORR	CORR	CAL. M	SUB	S/C TIM	MNFR SYNC	MJFR SYNC	M.L. STRT	LINE SUB.	P F	CP CR	NF NUP	ERR UPN
4	4026414595	4R0070250264	001	0 0 0 0	0	0	0	1096	H	26921	1	0	0	0	0	G	0	0	0

HOT-AM BAND TRIG TIMES: 1) 0000000000 : 0000000000 2) 0000000000 : 0000000000 3) 0000000000 : 0000000000 4) 0000000000 : 0000000C00

RADIOMETRIC IMAGE QUALITY

NOMINAL CAL WEDGE SET ID:

MULT/ADD CONSTANT SET ID:

CALIBRATION METHOD : H
CALIBRATION SEGMENTS : 4
CALIBRATION SUBSEGMENTS: 3

BAND DATA

BAND NO.	QUAL CODE	QUALITY CNTS : 00	02	03	SENSOR MODE	HISTOGRAMS : MEAN	DIFF	STDV	SWEEPS MISS	C.W. WINDOW
1	0	2400	0	0	LC	75.9	4.0	29.27	0	0
2	0	2400	0	0	LC	80.9	3.2	32.19	0	0
3	0	2400	0	0	LC	83.4	6.3	30.84	0	0
4	0	2400	0	0	LL	32.3	9.1	13.02	0	0

Radiometric Indicators

Max Difference Between
Detectors Within Each Band
= 3 Initially

DETECTOR DATA

SCN DET	C.W. SUB.	CALIBRATION : GAIN	BIAS	GAIN	HISTOGRAM : BIAS	MEAN	STDV
1	1200	0.7	0.6	0.6	0.4	75.7	28.90
2	1200	0.7	1.7	0.7	1.9	75.9	29.16
3	1200	0.8	0.5	0.8	1.5	76.1	29.40
4	1200	0.9	2.3	0.8	1.6	75.6	28.83
5	1200	0.6	2.6	0.7	3.6	76.5	30.01
6	1200	0.8	2.3	0.8	2.3	75.9	29.31
7	1171	0.9	0.9	0.9	1.1	80.8	32.14
8	1006	0.9	0.8	1.0	2.4	81.2	32.56
9	1191	0.8	1.0	0.6	1.3	81.0	32.35
10	982	0.8	0.7	0.8	1.6	81.0	32.26
11	966	0.9	0.5	0.9	1.6	80.9	32.23
12	5	0.8	4.5	0.8	1.8	80.4	31.61

SCN DET	C.W. SUB.	CALIBRATION : GAIN	BIAS	GAIN	HISTOGRAM : BIAS	MEAN	STDV
13	1200	0.7	1.8	0.7	1.2	83.2	30.31
14	1200	0.7	0.5	0.7	0.8	83.4	30.87
15	1200	0.9	3.5	0.9	3.0	83.5	30.89
16	1200	0.9	1.8	0.9	2.4	83.5	30.90
17	1200	0.9	1.9	0.9	1.6	83.2	30.56
18	1200	1.0	1.5	1.0	2.9	83.9	31.50
19	1200	0.9	0.8	0.9	0.5	32.3	13.04
20	1200	0.9	0.7	0.9	0.6	32.3	13.03
21	1200	0.9	0.7	0.9	1.3	32.3	13.00
22	1200	0.8	2.2	0.8	1.3	32.3	13.0.
23	1200	0.9	1.1	0.9	0.8	3..3	13.00
24	1200	0.9	-0.1	0.9	0.9	32.3	13.04

Overall and Quality Code

- Located in Byte 146 of HDT Header Data
- Ranges From 0 - 9, A,B,C   0 — Acceptable
  C — Best
- f (Geometric Correction Quality, Radiometric Correction Quality, Image Data Quality
- Geometric Correction Quality

Code	Parameters Modeled
A —	No Parameter Modeled
G —	Along Track, Across Track (Uses Control Points for Translation Errors)
E —	Along Track, Across Track, Yaw, Altitude

- Radiometeric Correction Quality (RCA—Max. Difference Between Detector Means for Image)

Code	Criteria
E	0< Relative Calibration Accuracy <1.0
G	1.0< RCA <2.0
A	2.0< RCA

- Image Data Quality $\left(DQI = \frac{MJ\ FSL + MiFSL}{20} + \frac{Unrecov.\ ECC}{20} \right)$

Code	Criteria
E	$0 \leq DQI \leq 1.5$
G	$1.5 \leq DQI \leq 4.5$
A	$4.5 < DOI$

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Process Evaluation

Problem Investigation

- PDR Investigations by Quality Analysts and Image Processing Analysts
- PDR Processing and Management Reports by PDR Coordinator
- Problem Trend Analysis By Image Processing Analysts Using PDR's and ESR's and Data Base

Process Quality Assessment

- Processing Success Evaluation by Image Processing Analyst Using Processing and QA Reports
- Operation Audits of All Functions by Quality Analysts
- Refinement of Use of Quality Indicators by Quality Analysts
- Processing Enhancement Recommendations
- Line Tests
  - — Evaluate Results and Authorize Processing—Quality Analysts
  - — Criteria Development and Evaluation—Image Processing Analysts (Approved by ERB)

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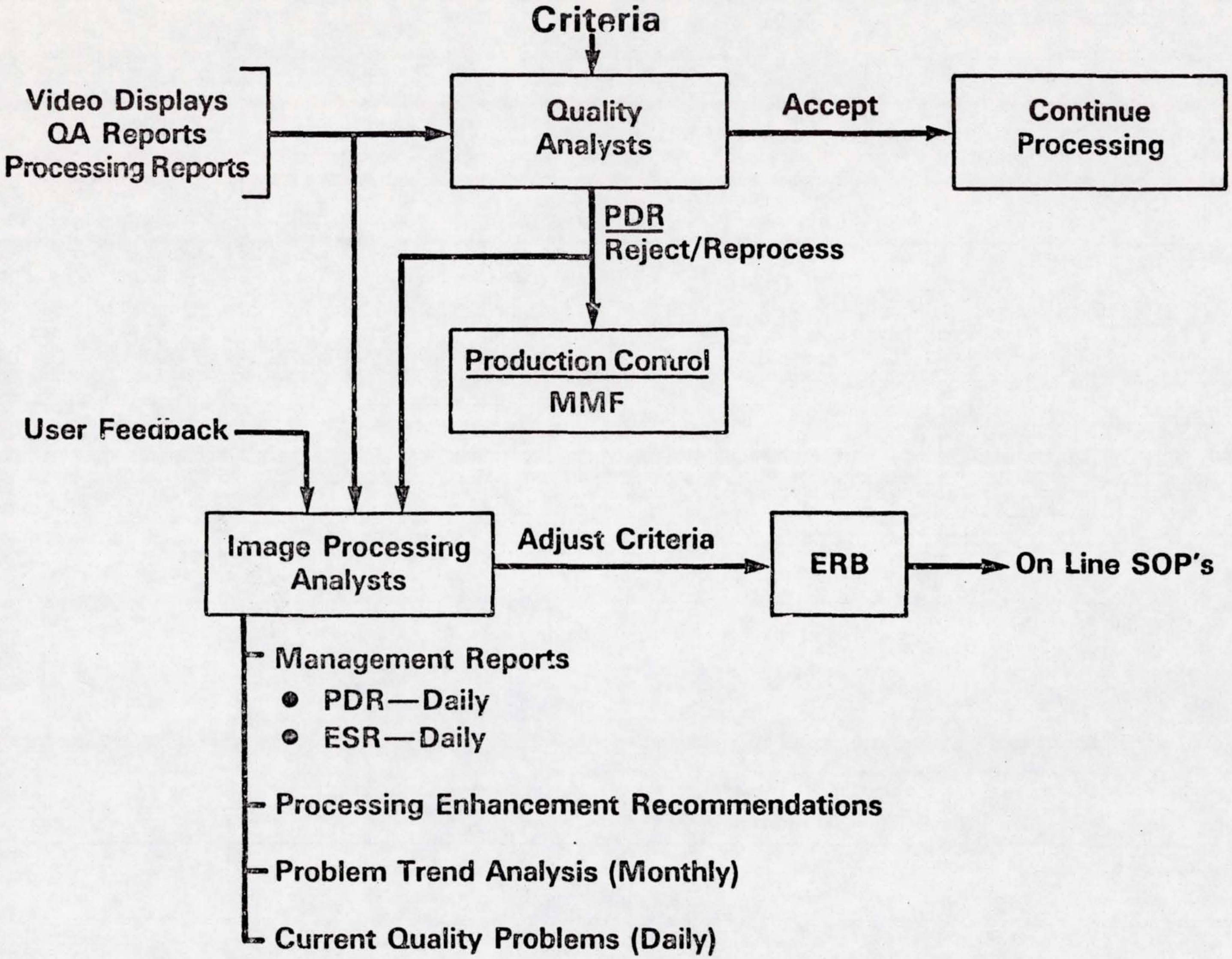
Management Reporting

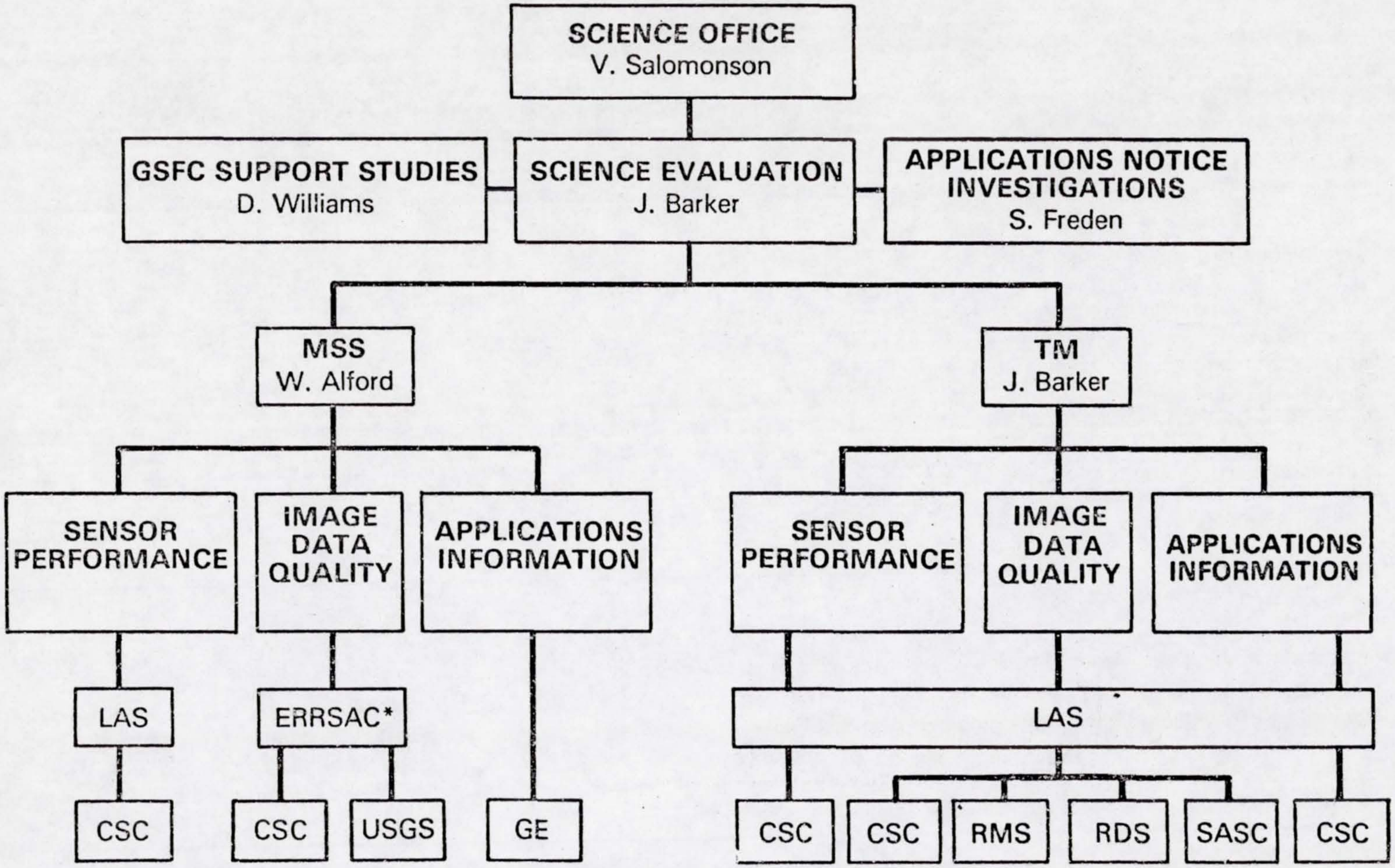
- Automated Management Reports for PDR's and ESR's
- Audit Reports
  - — Immediate Reports to Responsible Manager
  - — Corrective Action Reports Required
  - — Management Report
- Special Management Reports
  - — Problem Trend Analysis (Monthly)
  - — Current Quality Problems (Daily)

Accept/Reject/Reprocess Flow



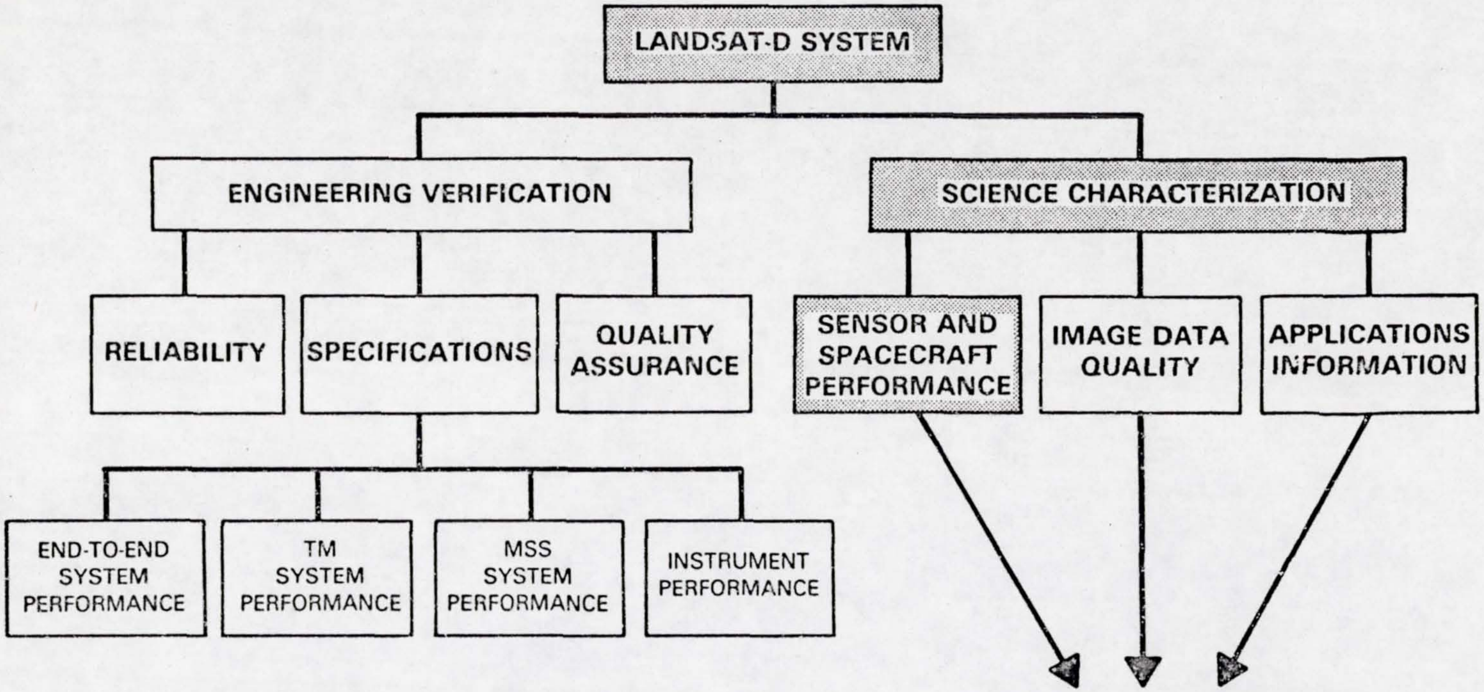
Science Characterization

Science Organization



*Eastern Regional Remote Sensing Application Center

Structure



- Recommend Landsat-D System Improvements
- Communicate Results to Research Community

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Sensor and Spacecraft Performance Characterization

AREAS OF INVESTIGATION

RADIOMETRY

A. Spectral Resolution

1. Filter
2. Detectors
3. System

B. Radiometric Resolution

1. Absolute Integrating Sphere Calibration (Dynamic Range Linearity, S/N)
2. External Calibration (Precision)
3. Internal Calibration (Precision, S/N)
4. Flooding Lamp Calibration (Uniformity Over Scan)

Sensor and Spacecraft Performance Characterization

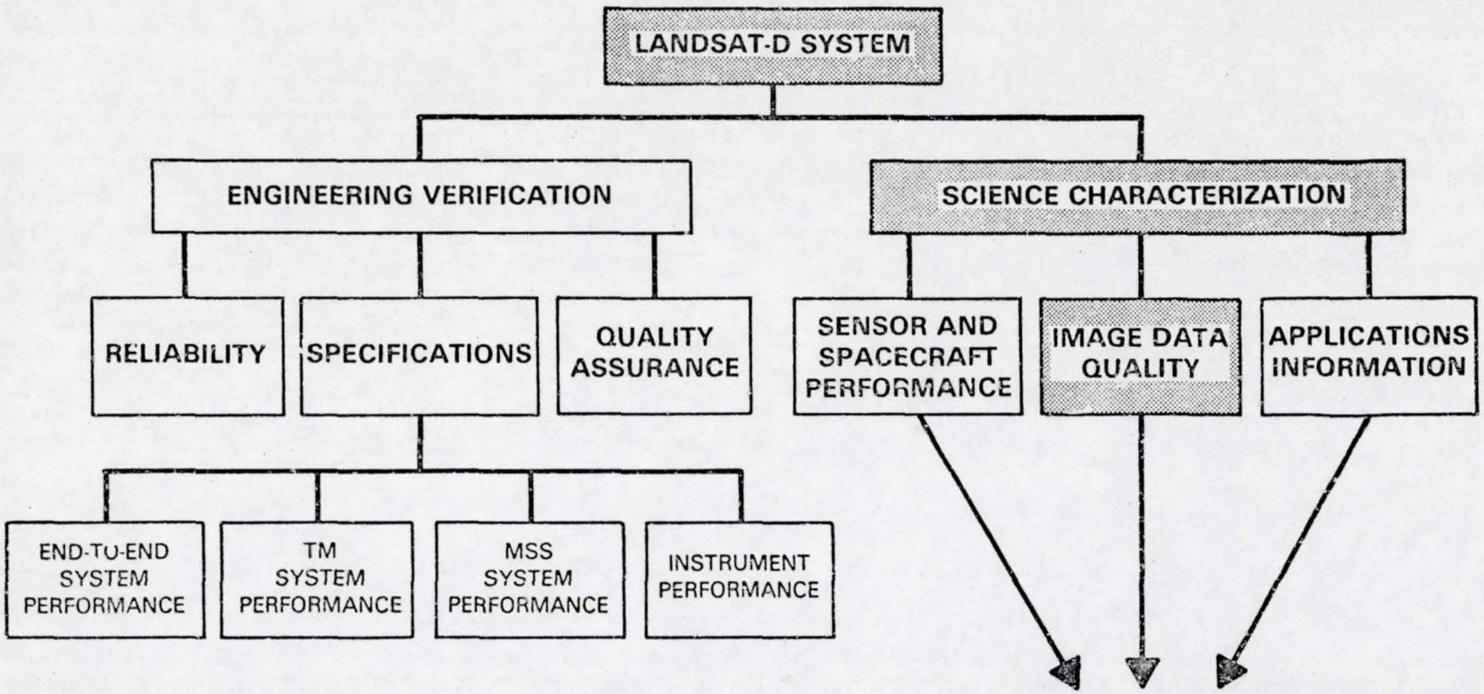
AREAS OF INVESTIGATION (CONT.)

GEOMETRY

A. Geometry of Pixel
   1. Rise Time and Delay Time
   2. Bright Target Recovery Time
   3. MTF (IFOV) or Frequency Response Time
   4. Bowtie Scan Angle Effect
   5. Altitude Effects

B. Geometry of Image (Pixel Location)
   1. Sensor Effects
      A. Scan Profile for Reference Detector
         - Along and Across Scan
         - Forward and Reverse Scan
      B. Detector Location Relative to Reference Detector
         - Band-to-Band Registration
         - Forward and Reverse Scan
      C. Between Scan Alignment
         - Reference Detector Forward and Reverse Offset
         - Along and Across Scan
   2. Ephemeris
      A. Orbital Support Computing Division (OSCD)
      B. Global Positioning System (GPS)
   3. Attitude
      A. Angular Displacement Sensor (ADS)
      B. Inertial Reference System (DRIRU)
      C. Attitude Control System (ACS)
      D. Alignment to Sensor (ADS, DRIRU and ACS)

Structure



- Recommend Landsat-D System Improvements
- Communicate Results to Research Community

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Image Data Quality Performance Characterization

AREAS OF INVESTIGATION

RADIOMETRY

A. Spectral Information

1. Detector Replacement Algorithms
2. Band Compression Algorithms

B. Radiometric Information

1. Internal Calibration Algorithms
   - A. Channel-to-Channel
   - B. Band-to-Band
2. Scene Histogram Calibration Algorithms (Radiometric Destriping)
3. Absolute Scene Radiance Calibration Algorithms
   - A. Reflective Band
   - B. Thermal Band
4. Noise Correction Algorithms

Image Data Quality Performance Characterization

AREAS OF INVESTIGATION (CONT.)

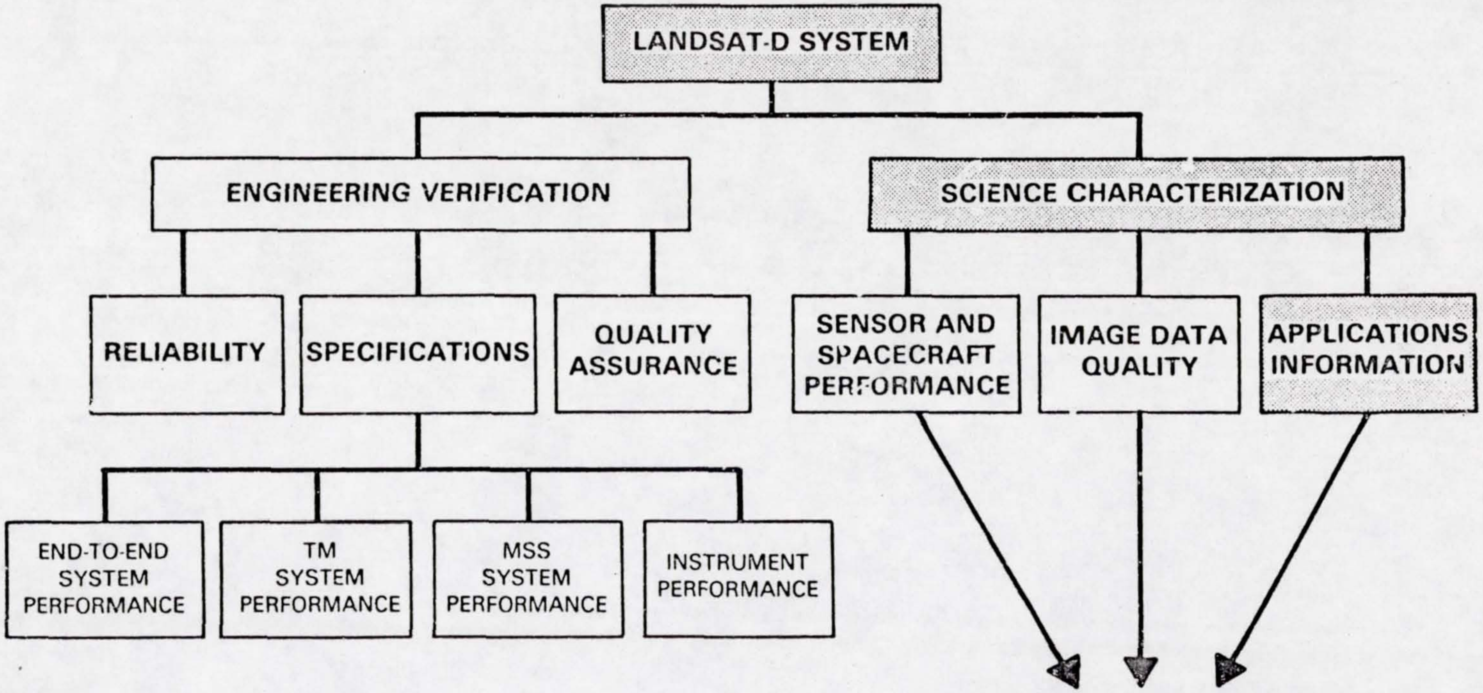
GEOMETRY

A. Geometry of Pixel (Ground IFOV)

B. Geometry of Image (Pixel Location)

1. Systematic Correction
   - A. Scan Profile
   - B. Detector Location (Forward and Reverse Scan Alignment, Gap and Overlap)
   - C. Between Scan Alignment
   - D. Ephemeris
   - E. Attitude
2. Geodetic Correction with Ground Control Points (GCPs)
   - A. Reference Library Build (Scene-to-Map Rectification)
   - B. Scene-to-Reference Scene Registration
3. Resampling

Structure



- Recommend Landsat-D System Improvements
- Communicate Results to Research Community

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Applications Information — MSS and TM

Areas of Interest

RENEWABLE RESOURCES	NON-RENEWABLE RESOURCES	PLANNING/ENVIRONMENTAL MANAGEMENT
Agriculture	**Geology**	**Regional/Urban Lane Use**
Inventory	Structure	Cover Classification
Yield	Landforms	Cover Change
Condition	Lithology	Environmental Impact
Irrigation	Thermal Anomalies	**Coastal Zone**
Episodal Event	Geobotanical Anomalies	Monitoring
Soils	Topography (Stereo)	**Hydrology**
Classification	Episodal Event	Drainage Patterns
Erosion	**Image-Science**	Inland Water Inventory
Moisture	Pattern Recognition	Snow Pack Parameters
Forests	Information Extraction	Ice — Inland & Near Shore
Inventory		Water Quality — Inland & Near Shore
Stand Evaluation		Wetland/Estuaries Inventory
Condition		Episodal Event
Episodal Event		**Wildlife Habitat**
Range		Inventory
Vegetation Inventory		Evaluation
Condition		**Oceans**
Episodal Event		Currents (Near Shore)
		Tides
		Bathymetric Charts
		Ocean Pollution (Near Shore)

Sensor and Spacecraft Performance Characterization — MSS

			Name	Colewell	Bernstein	Anuta	Malila	Bender	Price	Slater	Wrigley	Malila	Zobrist	Erickson	Hovis	Lauer	Schott	Keiffer	Welch	Pozier	Guerney	Hill	Everett	MacDonald	Anderson
			GSFC No.	AN 3	AN 8	AN 9	AN 12	AN 14	AN 15	AN 18	AN 20	AN 23	AN 25	AN 26	AN 29	AN 31	AN 32	AN 35	AN 36	AN 37	AN 39	AN 41	AN 42	AN 44	AN 46
Radiometry	Spectral Resolution	Spectral Matching	Filter																						
Radiometry	Spectral Resolution	Spectral Matching	Detectors																						
Radiometry	Spectral Resolution	Spectral Matching	System					●		●		●													
Radiometry	Radiometric Resolution	Aboslute Integrating Sphere Calibration																							
Radiometry	Radiometric Resolution	External Calibration				●		●		●		●													
Radiometry	Radiometric Resolution	Internal Calibration	Precision									●													
Radiometry	Radiometric Resolution	Internal Calibration	Signal-to-Noise			●		●				●													
Radiometry	Radiometric Resolution	Flooding Lamp Calibration																							
Geometry	Geometry of Pixel	Rise Time & Delay Time		●																					
Geometry	Geometry of Pixel	Bright Target Recovery Time		●																					
Geometry	Geometry of Pixel	MTF (IFOV) or Frequency Response Time		●																					
Geometry	Geometry of Pixel	Bowtie Scan Angle Effect		●		●																			
Geometry	Geometry of Pixel	Altitude Effects		●		●							●												
Geometry	Geometry of Image (Pixel Location)	Sensor Effects	Scan Profile, Reference Detector		●	●		●										●							
Geometry	Geometry of Image (Pixel Location)	Sensor Effects	Detector Location Relative to Reference Detector			●		●										●							
Geometry	Geometry of Image (Pixel Location)	Sensor Effects	Between Scan Alignment			●												●							
Geometry	Geometry of Image (Pixel Location)	Ephemeris	Orbital Support Competing Div.																						
Geometry	Geometry of Image (Pixel Location)	Ephemeris	Global Positioning System (GPS)																						
Geometry	Geometry of Image (Pixel Location)	Attitude	Angular Displacement Sensor (ADS)																						
Geometry	Geometry of Image (Pixel Location)	Attitude	Inertial Reference System (DRIRU)																						
Geometry	Geometry of Image (Pixel Location)	Attitude	Attitude Control System (ACS)																						
Geometry	Geometry of Image (Pixel Location)	Attitude	Alignment to Sensor																						

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Image Data Quality Performance Characterization — MSS

		Name		Colewell	Bernstein	Anuta	Malila	Bender	Price	Slater	Wrigley	Malila	Zobrist	Erickson	Hovis	Lauer	Schott	Koffler	Welch	Pozner	Guerney	Hill	Everett	MacDonald	Anderson						
		GSFC No		AN 3	AN 8	AN 9	AN 12	AN 14	AN 15	AN 18	AN 20	AN 23	AN 25	AN 26	AN 29	AN 31	AN 32	AN 35	AN 36	AN 37	AN 39	AN 41	AN 42	AN 44	AN 46						
Geometry	Spectral Information	Detector Replacement Algorithms				●																									
Geometry	Spectral Information	Band Compression Algorithms																													
Geometry	Radiometric Information	Internal Calibration Algorithms	Channel to Channel			●									●																
Geometry	Radiometric Information	Internal Calibration Algorithms	Band to Band			●									●																
Geometry	Radiometric Information	Scene Histogram Calibration Algorithms (Radiometric Destriping)			●	●						●																			
Geometry	Radiometric Information	Absolute Scene Radiance Calibration Algorithms	Reflective Band	●				●		●																					
Geometry	Radiometric Information	Absolute Scene Radiance Calibration Algorithms	Thermal Band	●						●																					
Geometry	Radiometric Information	Noise Correction Algorithms				●							●																		
Radiometry	Geometry of Pixel	Ground IFOV			●																										
Radiometry	Geometry of Image (Pixel Location)	Systematic Correction	Scan Profile		●	●																									
Radiometry	Geometry of Image (Pixel Location)	Systematic Correction	Detector Location		●	●		●										●													
Radiometry	Geometry of Image (Pixel Location)	Systematic Correction	Between Scan Alignment																												
Radiometry	Geometry of Image (Pixel Location)	Systematic Correction	Ephemeris																												
Radiometry	Geometry of Image (Pixel Location)	Systematic Correction	Attitude			●																									
Radiometry	Geometry of Image (Pixel Location)	Geodetic Correction with GCPs	Reference Library Build		●			●			●	●						●													
Radiometry	Geometry of Image (Pixel Location)	Geodetic Correction with GCPs	Scene to Reference Registration		●			●			●	●	●					●													
Radiometry	Geometry of Image (Pixel Location)	Resampling																													

Sensor and Spacecraft Performance Characterization — TM

			Name	Colwell	Bernstein	Anuta	Malila	Bender	Price	Slater	Wrigley	Malila	Zobrist	Erickson	Hovis	Lauer	Schott	Keiffer	Welch	Pozier	Guerney	Hill	Everett	MacDonald	Anderson
			GSFC No.	AN 3	AN 8	AN 9	AN 12	AN 14	AN 15	AN 18	AN 20	AN 23	AN 25	AN 26	AN 29	AN 31	AN 32	AN 35	AN 36	AN 37	AN 39	AN 41	AN 42	AN 44	AN 46
Radiometry	Spectral Resolution	Spectral Matching	Filter																						
Radiometry	Spectral Resolution	Spectral Matching	Detectors																						
Radiometry	Spectral Resolution	Spectral Matching	System					●		●														●	
Radiometry	Radiometric Resolution	Abosiute Integrating Sphere Calibration									●														
Radiometry	Radiometric Resolution	External Calibration				●		●		●	●			●	●		●							●	
Radiometry	Radiometric Resolution	Internal Calibration	Precision																						
Radiometry	Radiometric Resolution	Internal Calibration	Signal to Noise			●		●						●										●	
Radiometry	Radiometric Resolution	Flooding Lamp Calibration																							
Geometry	Geometry of Pixel	Rise Time & Delay Time		●	●																				
Geometry	Geometry of Pixel	Bright Target Recovery Time		●	●																				
Geometry	Geometry of Pixel	MTF (IFOV) or Frequency Response Time		●	●	●					●			●					●						
Geometry	Geometry of Pixel	Bowtie Scan Angle Effect			●	●																			
Geometry	Geometry of Pixel	Altitude Effects			●	●							●												
Geometry	Geometry of Image (Pixel Location)	Sensor Effects	Scan Profile, Reference Detector		●	●		●			●							●			●				
Geometry	Geometry of Image (Pixel Location)	Sensor Effects	Detector Location Relative to Reference Detector	●	●	●		●			●			●				●					●		
Geometry	Geometry of Image (Pixel Location)	Sensor Effects	Between Scan Alignment		●	●																			
Geometry	Geometry of Image (Pixel Location)	Ephemeris	Orbital Support Competing Div.																						
Geometry	Geometry of Image (Pixel Location)	Ephemeris	Global Positioning System (GPS)																						
Geometry	Geometry of Image (Pixel Location)	Attitude	Angular Displacement Sensor (ADS)																						
Geometry	Geometry of Image (Pixel Location)	Attitude	Inertial Reference System (DRIRU)																						
Geometry	Geometry of Image (Pixel Location)	Attitude	Attitude Control System (ACS)																						
Geometry	Geometry of Image (Pixel Location)	Attitude	Alignment to Sensor																						

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Image Data Quality Performance Characterization — TM

			Name	Coiswell	Bernstein	Anuta	Malila	Bender	Price	Slater	Wrigley	Malila	Zobrist	Erickson	Hovis	Lauer	Schott	Keiffer	Welch	Pozier	Guerney	Hill	Everett	MacDonald	Anderson
			GSFC No.	AN 3	AN 8	AN 9	AN 12	AN 14	AN 15	AN 18	AN 20	AN 23	AN 25	AN 26	AN 29	AN 31	AN 32	AN 35	AN 36	AN 37	AN 39	AN 41	AN 42	AN 44	AN 46
Geometry	Spectral Information	Detector Replacement Algorithms				●																			
		Band Compression Algorithms																							
	Radiometric Information	Internal Calibration Algorithms	Channel-to-Channel			●									●									●	
			Band-to-Band			●									●										
		Scene Histogram Calibration Algorithms (Radiometric Destriping)			●	●									●		●						●	●	
		Absolute Scene Radiance Calibration Algorithms	Reflective Band	●				●		●					●								●		
			Thermal Band	●						●							●								
		Noise Correction Algorithms				●								●											
Radiometry	Geometry of Pixel	Ground IFOV			●						●														
	Geometry of Image (Pixel Location)	Systematic Correction	Scan Profile		●	●												●			●		●		
			Detector Location		●	●		●			●							●			●		●		
			Between Scan Alignment																						
			Ephemeris										●										●		
			Attitude			●					●							●			●		●		
		Geodetic Correction with GCPs	Reference Library Build		●			●					●					●			●				
			Scene-to-Reference Registration		●			●			●		●	●				●						●	
		Resampling																							

Applications Information — MSS & TM

	Name	Colewell	Bernstein	Anuta	Malila	Bender	Price	Slater	Wrigley	Malila	Zobrist	Erickson	Hovis	Lauer	Schott	Keiffer	Welch	Pozier	Guerney	Hill	Everett	MacDonald	Anderson						
	GSFC No.	AN 3	AN 8	AN 9	AN 12	AN 14	AN 15	AN 18	AN 20	AN 23	AN 25	AN 26	AN 29	AN 31	AN 32	AN 35	AN 36	AN 37	AN 39	AN 41	AN 42	AN 44	AN 46						
Renewable Resources	Agriculture																												
	Soils																												
	Forests																												
	Range																												
	Other																												
Non-Renewable Resources	Geology																												
	Image Science																												
	Other																												
Planning/ Environmental Management	Regional/Urban Land Use																												
	Coastal Zone																												
	Hydrology																												
	Wildlife Habitat																												
	Oceans																												
	Other																												

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Investigations Workshop Schedule

FIRST WORKSHOP TIMING

TODAY IS TOO EARLY:

- Still in AN Contract Negotiation
- Much More Landsat-D Information Still to Come

TODAY IS TOO LATE:

- Less Than Two Months to Launch
- Already Buried in Data !
- Already More Questions Than Answers !

Investigations Workshop Objectives

- Provide Pre-Requisite Information on:
  - MSS & TM Radiometry and Geometry
  - Data Acquisition, Processing and Availability
  - Nature and Direction of Investigations Program
- Create the Investigations Team
- Get Help:
  - Review of Draft Reports
  - Refinement of AN Areas of Investigation
  - Identification of AN Data and Information Requirements

Investigations Workshop Activities

PROVIDING INFORMATION

- Workshop Presentations
- Thursday Evening Tours
  - Five Offered (½ Hour Each)
  - Select up to Four During 2 Hours Allotted
- Supporting Documentation (Tape Formats, Draft Reports, etc.)
  - Order Via Form Provided
  - Limited Quantity Available Today
  - Remainder of Order Filled by Mail

CREATING TEAM

- Investigations Team Interaction Opportunities
- Principal Investigator Meetings with Science Representatives

Investigations Workshop Activities (Cont.)

ASKING FOR HELP, **PLEASE:**

- Identify Specific Additional Information Required, When Desired and When Needed (Via Workshop Return Form)

- Review Indicated Draft Reports (Via Workshop Return Form)

- Locate Individual Investigation Area Within Matrix (Via X on Matrix in Meeting with Science Representative)

Early Access TM Processing

John Lyon

Landsat-D Assessment System

SYSTEM OBJECTIVES

TM EARLY ACCESS PROGRAM (SCROUNGE)

- Provide, In Concert with the Applications Developmental Data System and Components of the Ground Segment, the Only TM Products Available in the First Year of Orbital Operations
  - One Scene/Day Using A Priori Corrections
  - Standard Products: P Film and Digital Data on 6250 BPI Tapes
  - Also Available: A and "B" Data Sets as Necessary

RESEARCH/ANALYSIS DATA SYSTEM ALLIED WITH GROUND SEGMENT

- Open Ended/Flexible
- To Accomodate Meaningful Data Quality and Interpretation Studies v. Instruments, Emphasizing TM
- Available for AN Support with Some Resource Contention with Scrounge

Overall Configuration

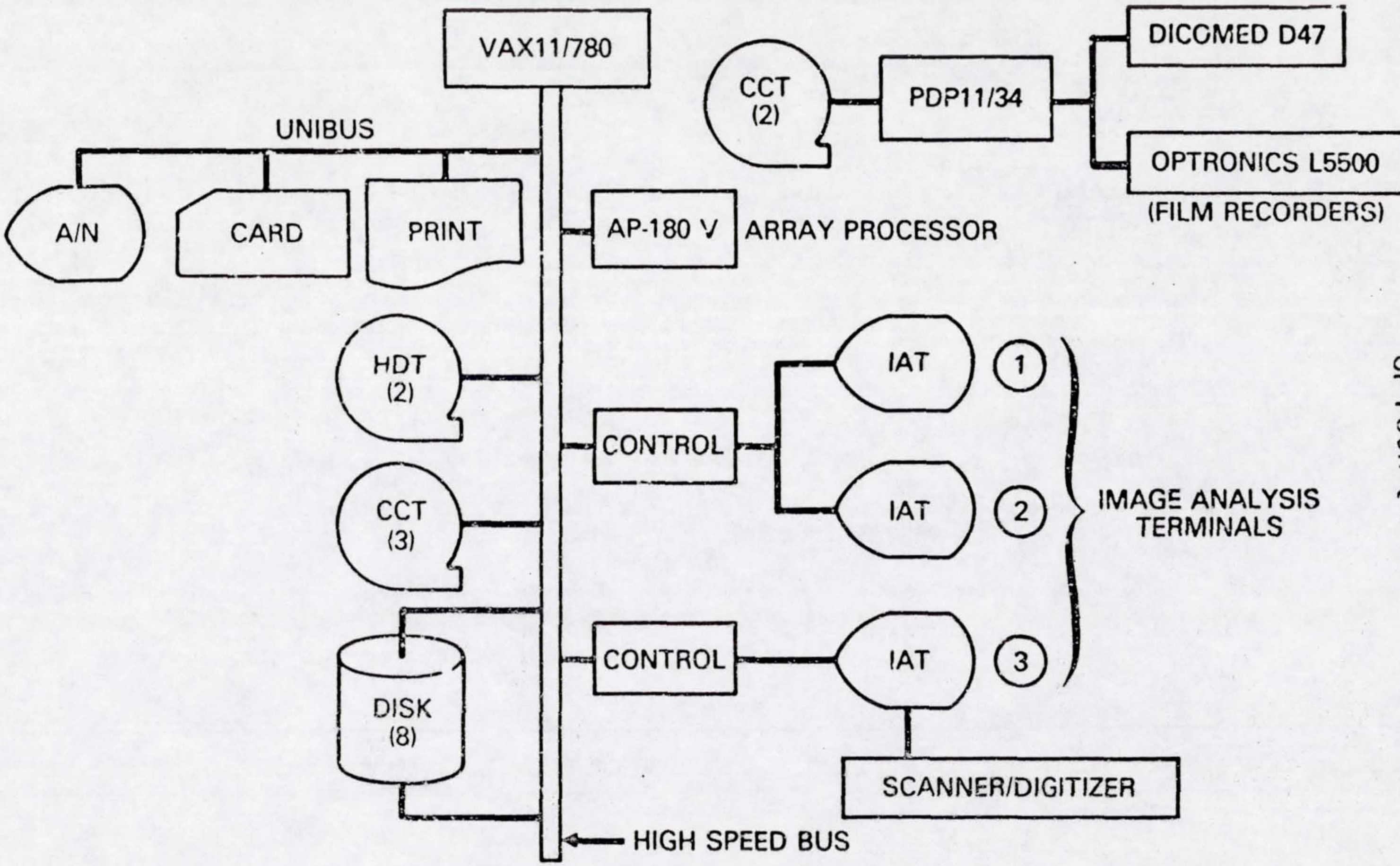

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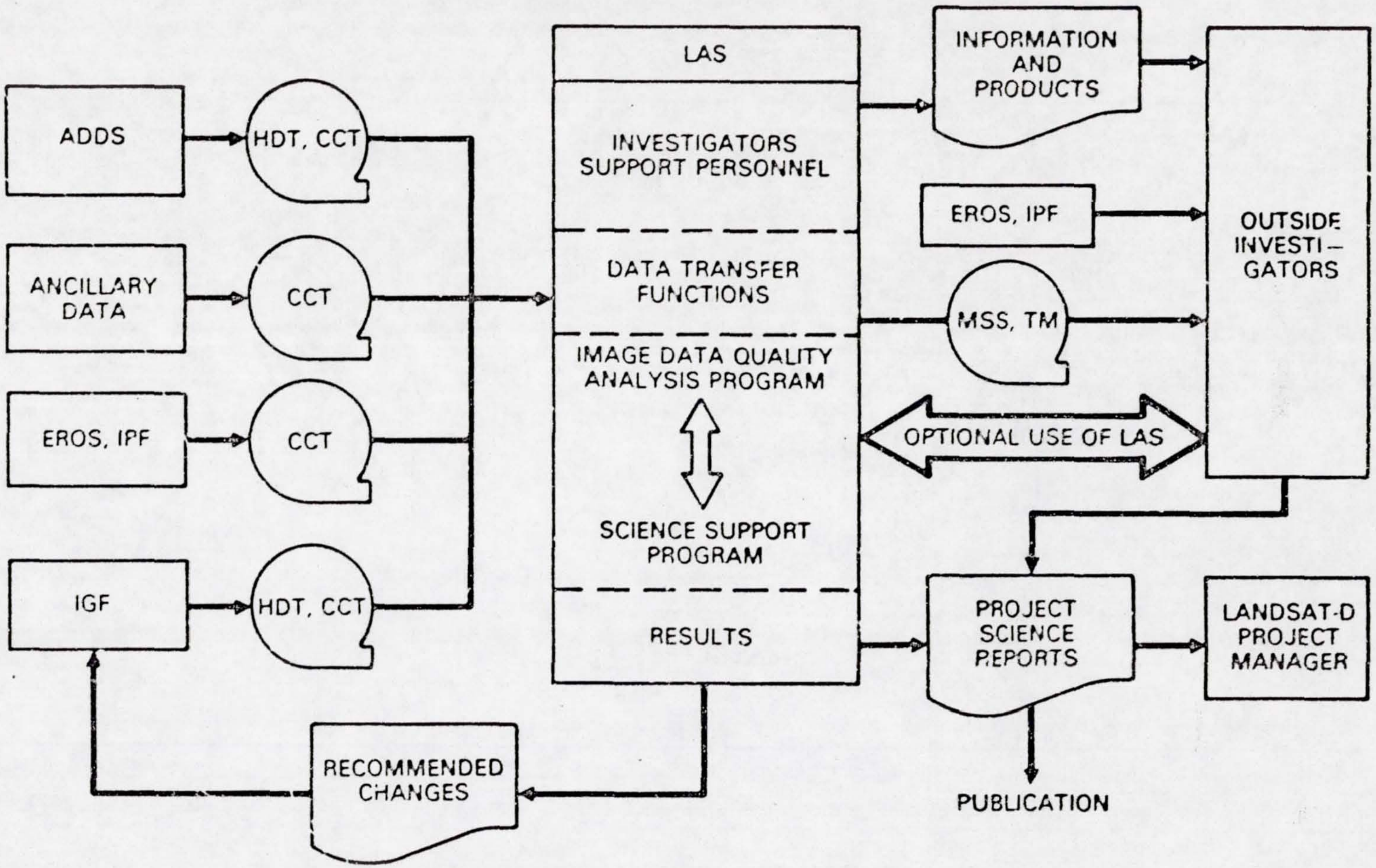
Image Data Quality Analysis/ Science Support Program



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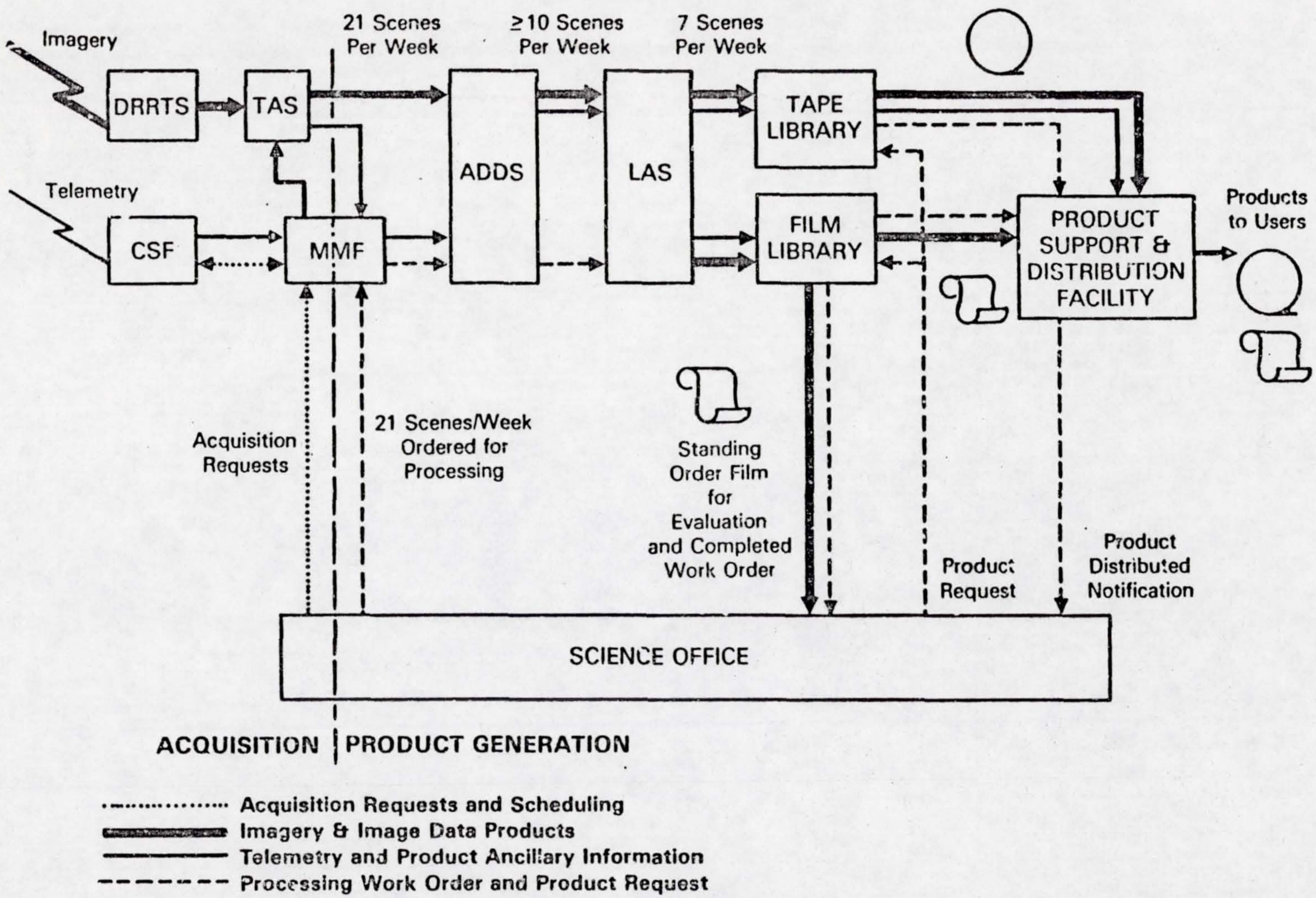
End-to-End Scrounge Data Flow



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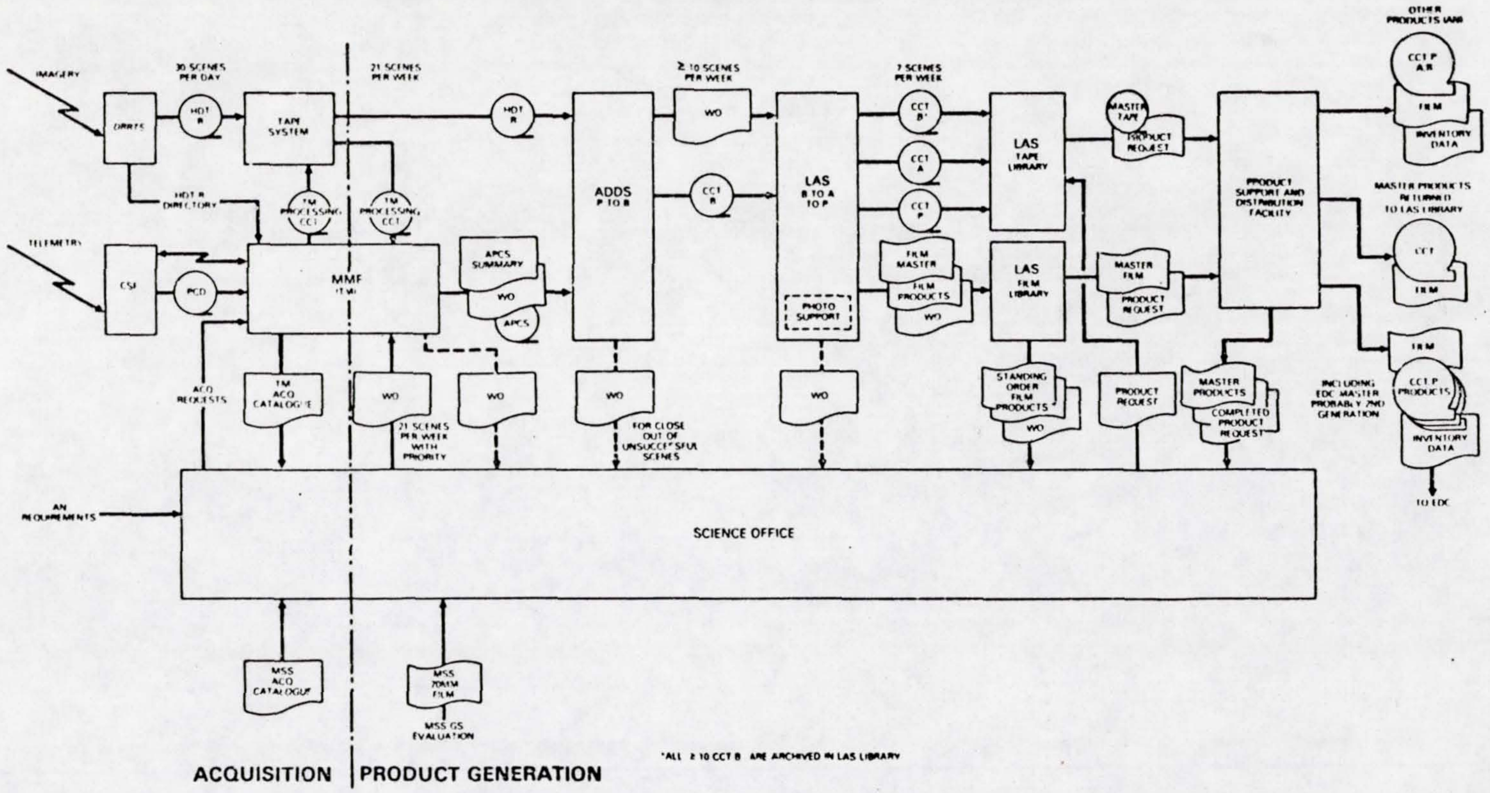
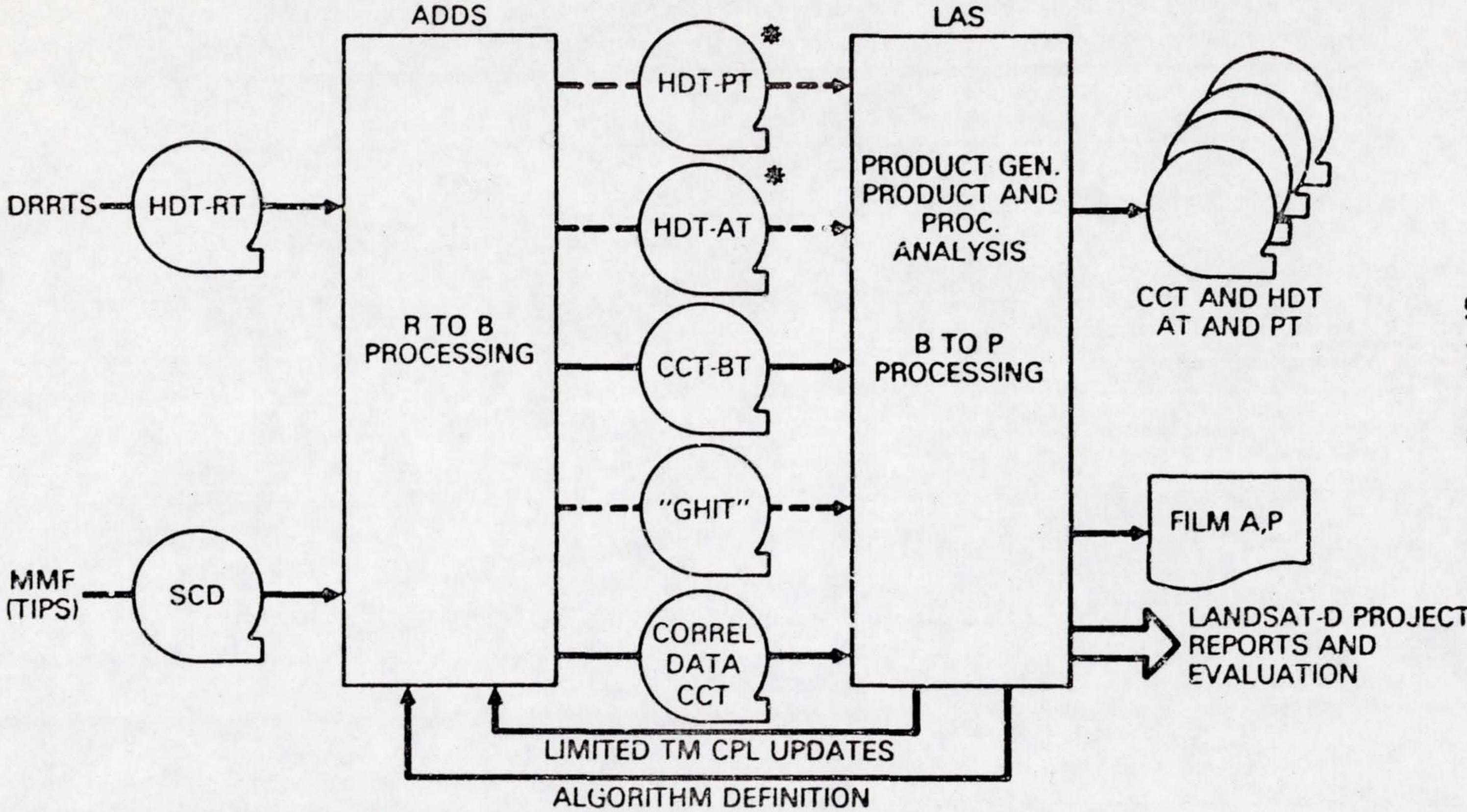
End to End Scrounge — LAS



LAS Functions

- Receive a Minimum of 10 and up to 21 TM Scenes Per Week in CCT-B Format
- Receive Corresponding Work Orders and Scene Priorities
- Apply Radiometric and Geometric Corrections to TM Data as Required to Produce CCT-A and P Products
- Produce TM P-Film Master and Associated Products for 7 Scenes Per Week
- Forward Standing Order Film Products and Updated Work Orders to Science Office
- Store Tape and Film Master in Respective Libraries
- Supply Film and Tape Masters to Products Support and Distribution Facility (According to Product Requests) for Preparation of Output Products
- Provide Science Office with Weekly Processing Summary Report

TM Early Access Program Functional Data Flow



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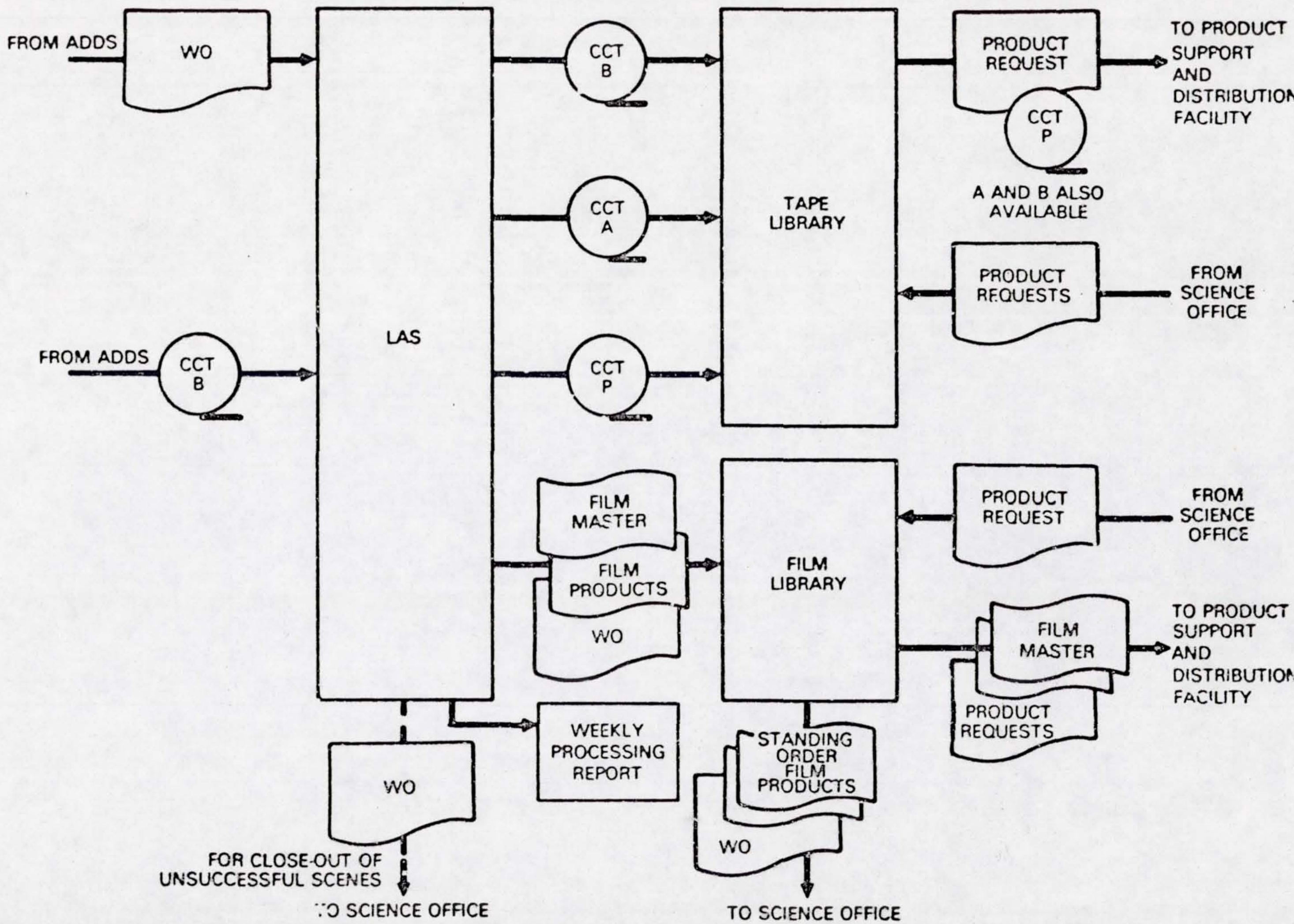
REQUIRED PERFORMANCE LEVEL 1 TM SCENE/DAY

MSS CORRELATIVE DATA AVAILABLE: IGF AND IPF

MAJOR FUNCTIONAL DATA FLOW
— TM PROCESSING —

LAS interfaces



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Landsat-D Data Acquisition and Availability

Stan Freden

Landsat-D Data Acquisition and Availability

- MSS Acquisition and Availability
- TM Acquisition and Availability
- AN Mission Options

MSS Data Acquisition and Availability

FIRST YEAR

Acquisition Capability:	200 Scenes/Day All US Except Hawaii
Acquisition Priorities:	First 6 Months—All Possible Data of US Consistent with Landsat-3/Landsat-D Station Conflicts After 6 Months—NOAA Responsibility, NASA Engineering/Special Requirements will be Met
Acquisition Requests:	All Go Through the EROS Data Center (EDC) AN Requirements Come to GSFC Science Office → EDC
Processing Capability/Priority:	200 Scenes/Day Soon After Launch All Data Processed and Distributed by EDC Some Engineering Data Available Through GSFC

Priorities for Loading Landsat-D MSS GCP Library (U.S.)

AREA	PATH/ROW
Washington, DC	15/33
Lubbock, TX area	29, 30, 31/36, 37
Grand Canyon, AZ	37, 38/35
Phoenix, AZ	37/37
Lake Powell, UT	37/34
San Francisco, CA	44/34
Los Angeles, CA	41/36
Chicago, IL	22, 23/31
White Sands, NM	33/37
Pennsylvania (especially Lancaster area)	(15/32)
Florida	
Midwest Agricultural Area (Iowa, Kansas, North Dakota, etc.)	
Eastern United States	
Western United States	
Rest of United States (48 states)	
Alaska	
Hawaii	

MSS Tape Products

FACILITY	PROCESSING LEVELS				
	NONE	RADIOMETRIC		GEOMETRIC	
	RAW	INTERNAL CALIBRATION	SCENE HISTOGRAM	SYSTEMATIC	GEODETIC
MIPS					
CCT-AM	X	X	X		
CCT-PM				X	NOTE
EDC					
CCT-PM			X	X	NOTE

Note: Available as Soon as GCP Library can be Loaded

TM Data Acquisition and Availability

FIRST YEAR

Acquisition Capability: 30 Scenes/Day Average
Eastern and Central 48 Prior to TDRSS
Total 48 + Some Alaska/Hawaii and Some Foreign After TDRSS

Acquisition Priorities: Disasters
A/N Requirements
US Agricultural Requirements
Other Specials/PAO, etc.

Acquisition Requests: Data Request Forms
Inputs to Science Office

- AN Requirements go to Technical Representatives
- Others to Dr. Stanley C. Freden
  NASA/Goddard Space Flight Center
  Code 902
  Greenbelt, MD 20771
  344-5818

LANDSAT-D

DATA REQUIREMENTS

THEMATIC MAPPER (TM)
AND
MULTISPECTRAL SCANNER (MSS)

PRINCIPAL INVESTIGATOR NAME ______________________

ADDRESS ______________________

____

____

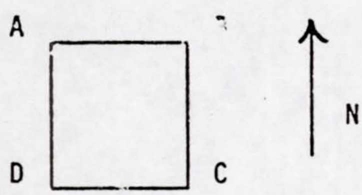
TELEPHONE NUMBER (US AND CANADA) ______________________

INVESTIGATION NUMBER ______________________

TEST SITE NUMBER ______________________

LOCATION ______________________

COORDINATES:



	LATITUDE D.M.S.	LONGITUDE D.M.S.
A.		
B.		
C.		
D.		

LANDSAT-D WRS
(Do not complete)

PATH	ROW

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DATA ACQUISITION SCHEDULE: DAY NIGHT

NIGHT JUSTIFICATION: ___ ______________________________

FIRST YEAR: (82) JUL AUG SEP OCT NOV DEC

(83) JAN FEB MAR APR MAY JUN

SECOND AND THIRD YEARS: (83/84) JUL AUG SEP OCT NOV DEC

(84/85) JAN FEB MAR APR MAY JUN

CLOUD COVER RESTRICTION: ______________%

ARE IN SITU DATA BEING COLLECTED CONCURRENTLY? YES NO

ANTICIPATED DATE(S) ______________________________

DATA PRODUCTS:

THEMATIC MAPPER:

	TAPES		FILM		
BAND	CCT-A	CCT-P	+P	+T	-T
1					
2					
3					
4					
5					
6					
7					

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MULTISPECTRAL SCANNER:*

	TAPES		FILM		
BAND	CCT-A	CCT-P	+P	+T	-T
1					
2					
3					
4					

1-125

* The Principal Investigator must order Multispectral Scanner data from the EROS Data Center. These data will be paid for by the Principal Investigator.

TM Data Acquisition and Availability (Cont.)

FIRST YEAR

Processing Capability = 1 Scene/Day = 7 Scenes/Week

Processing Priorities:
- Disasters
- A/N Requirements—Commonality, etc.
- US Agricultural Programs
- Other Specials

Processing Selection and Data Distribution:
- Screen and Select 21 "Cloud Free", "High Quality" Scenes Each Week in Priority Order
- Produce = 10 CCT-B's in ADDS for LAS
- Produce 7 "Processed" Scenes/Week in LAS
  - Provide Tape and Film Copying
  - Provide Tape and Film Distribution

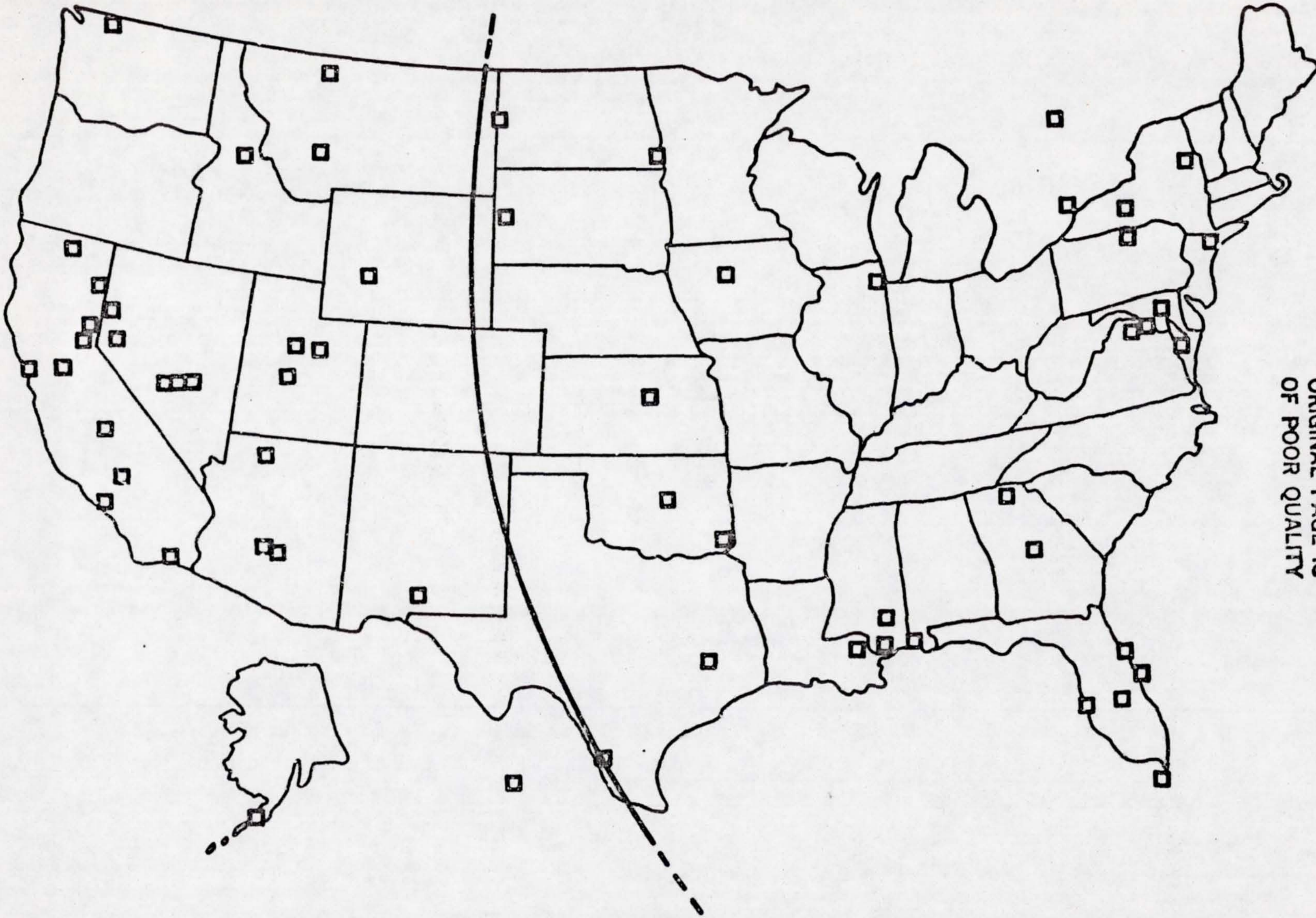
Expected Data Product Availability:
- ≈ 1 Scene/Cycle/AN Average
- Tapes and Film as Required
- Availability of First Processed Scene Upon Request for Analysis Systems Checkout

TM Tape Products

FACILITY	PROCESSING LEVELS				
	NONE	RADIOMETRIC		GEOMETRIC (NN OR CC RE-SAMPLING)	
	RAW	INTERNAL CALIBRATION	SCENE HISTOGRAM	SYSTEMATIC	GEODETIC
SCROUNGE (BEFORE JULY 83)					
CCT-BT	X				
CCT-AT		X	X		
CCT-PT		X	X	X	NOTE
TIPS					
CCT-AT	X	X	X		
CCT-PT		X	X	X	NOTE

Note: Available as Soon as GCP Library can be Loaded

Landsat-D Provisional Investigator Test Sites



Examples of AN Landsat-D Mission Options

- MSS On Alone
- TM On Alone
- MSS and TM On Together
- Daytime and Nighttime
- Choice of MSS Configuration
- Choice of TM Configuration

Introduction of Technical Experts and Science Representatives

John Barker

Introduction to MSS Pre-NOAA Characterization

Bill Alford

Landsat-D Science Office Pre NOAA MSS Characterization

OBJECTIVES

- Characterize Accuracy and Precision of Imagery
- Characterize Accuracy and Precision of Derived Information
- Recommend Landsat-D System Improvements
- Communicate Capabilities to Research Community

Landsat-D Science Office Pre NOAA MSS Characterization

AREAS OF INVESTIGATION

- Sensor Performance
- Image Data Quality
- Applications Information

SUPPORT

- Landsat-D Project
  - GE
  - Hughes Aircraft
  - CSC
  - ORI
- GSFC MSS Characterization Support
- Application Notice Investigations

Sensor and Spacecraft Performance Characterization
Radiometry of MSS

			Anuta	Bender	Slater	Malila								
Spectral Resolution	Spectral Matching	Filter												
		Detectors												
		System		●	●	●								
Radiometric Resolution	Absolute Integrating Sphere Calibration													
	External Calibration		●	●	●	●								
	Internal Calibration	Precision				●								
		Signal-to-Noise	●	●		●								
	Flooding Lamp Calibration													

Sensor and Spacecraft Performance Characterization
Geometry of MSS

			Bernstein	Anuta	Bender	Keiffer								
Geometry of Image (Pixel Location)	Sensor Effects	Scan Profile, Reference Detector	●	●	●	●								
		Detector Location Relative to Reference Detector		●	●	●								
		Between Scan Alignment		●		●								
	Ephemeris	Orbital Support Competing Div.												
		Global Positioning System (GPS)												
	Attitude	Angular Displacement Sensor (ADS)												
		Inertial Reference System (DRIRU)												
		Attitude Control System (ACS)												
		Alignment to Sensor												

Sensor and Spacecraft Performance Characterization
Geometry of MSS (con't)

		Colewell	Anuta	Zobrist									
Geometry of Pixel	Rise Time & Delay Time	●											
	Bright Target Recovery Time	●											
	MTF (IFOV) or Frequency Response Time	●											
	Bowtie Scan Angle Effect	●	●										
	Altitude Effects	●	●	●									

Image Data Quality Performance Characterization
Radiometry of MSS

			Colewell	Bernstein	Anuta	Bender	Slater	Malila	Zobrist	Hovis				
Spectral Information	Detector Replacement Algorithms				●									
	Band Compression Algorithms													
Radiometric Information	Internal Calibration Algorithms	Channel-to-Channel			●					●				
		Band-to-Band			●					●				
	Scene Histogram Calibration Algorithms (Radiometric Destriping)			●	●			●						
	Absolute Scene Radiance Calibration Algorithms	Reflective Band	●			●	●							
		Thermal Band	●				●							
	Noise Correction Algorithms				●				●					

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Image Data Quality Performance Characterization
Geometry of MSS

			Bernstein	Anuta	Bender	Wrigley	Malila	Zobrist	Keiffer					
Geometry of Pixel	Ground IFOV		●											
Geometry of Image (Pixel Location)	Systematic Correction	Scan Profile	●	◐										
		Detector Location	●	●	●				●					
		Between Scan Alignment												
		Ephemeris												
		Attitude		●										
	Geodetic Correction with GCPs	Reference Library Build	●		●	●	●		●					
		Scene-to-Scene Registration	●		●	●	●	●	●					
	Resampling													

Applications Information — MSS and TM

Areas of Interest

RENEWABLE RESOURCES

Agriculture
- Inventory
- Yield
- Condition
- Irrigation
- Episodal Event

Soils
- Classification
- Erosion
- Moisture

Forests
- Inventory
- Stand Evaluation
- Condition
- Episodal Event

Range
- Vegetation Inventory
- Condition
- Episodal Event

NON-RENEWABLE RESOURCES

Geology
- Structure
- Landforms
- Lithology
- Thermal Anomalies
- Geobotanical Anomalies
- Topography (Stereo)
- Episodal Event

Image-Science
- Pattern Recognition
- Information Extraction

PLANNING/ENVIRONMENTAL MANAGEMENT

Regional/Urban Lane Use
- Cover Classification
- Cover Change
- Environmental Impact

Coastal Zone
- Monitoring

Hydrology
- Drainage Patterns
- Inland Water Inventory
- Snow Pack Parameters
- Ice – Inland & Near Shore
- Water Quality – Inland & Near Shore
- Wetland/Estuaries Inventory
- Episodal Event

Wildlife Habitat
- Inventory
- Evaluation

Oceans
- Currents (Near Shore)
- Tides
- Bathymetric Charts
- Ocean Pollution (Near Shore)

GSFC Radiometric Characterization

- Destriping Analysis
  - Detector Histogram Comparisons
  - Bright to Dark Area Comparisons
  - Visual, Clustering and Classification Qualitative Tests
- Dynamic Range
- Signal-to-Noise

GSFC Geometric Characterization

- Geodetic Rectification Accuracy

  Compare with Intense Array of Verification Points

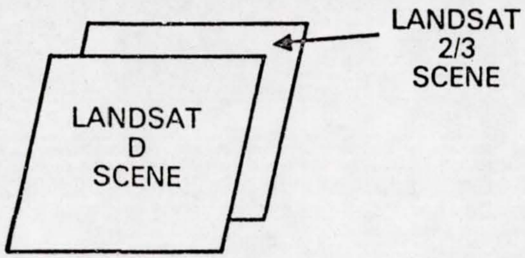
- Temporal Registration Accuracy

  Cross Correlate Temporal Scene with Geodetic Verified Scene

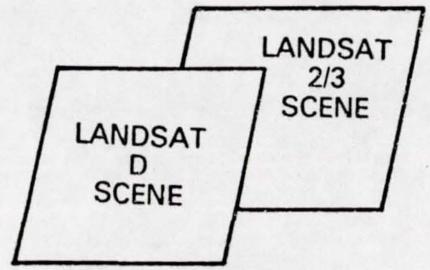
- Systematic Correction Accuracy
  - Cross Correlate With Geodetic Verified Scene
  - Band to Band Correlation to Measure Band Offsets
  - Analysis of MIPS Derived Parameters for Attitude/Ephemeris (GE)
  - Define Scan Non-Linearity (GE)

Landsat-D vs. Landsat 2/3 Geometric Accuracy

- Within Scene Comparisons as a Function of WRS Offset

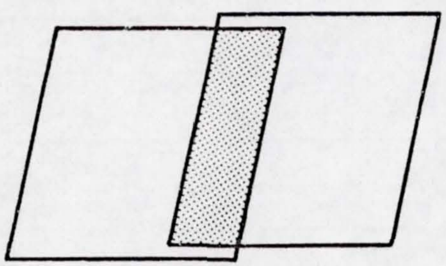


Minimum WRS Offset

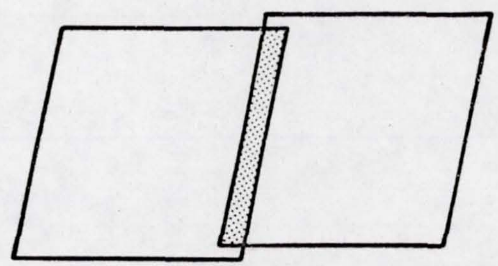


Maximum WRS Offset

- Adjacent Scene Overlap Area Comparisons



Landsat-2/3 Overlap



Landsat-D Overlap (Smaller Than for 2/3)

Landsat-D
Pre-NOAA MSS Characterization
Reports & Schedules

REPORTS	1982												1983											
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Hughes MSS Final Report				○		△																		
GE Geometric Calibration Report									△															
GE Radiometric Calibration Report									△															
GE Geometric Evaluation Report													△											
GE Radiometric Evaluation Report													△											
CSC MSS Radiometric Calibration Report					○				△															
ORI MSS Geometric Correction Report					○				△															
GSFC MSS Characterization Report									○		△													
Applications Notice Investigations MSS Applications Information Report										○		△												
Applications Notice Investigations MSS Characterization Report										○		△												

Final = △
Draft = ○

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MSS Radiometric Sensor Performance

- Spectral Information
- Absolute Calibration
- Ground Segment

John Barker

LANDSAT-D MSS RADIOMETRY

OBJECTIVES

TODAY

DOCUMENT SPECTRAL CHARACTERISTICS

DOCUMENT ABSOLUTE RADIOMETRIC LAMP CALIBRATION

DOCUMENT POST-LAUNCH RADIOMETRIC PREPROCESSING PROCEDURE

FUTURE

RECALIBRATE AND VALIDATE POST-LAUNCH

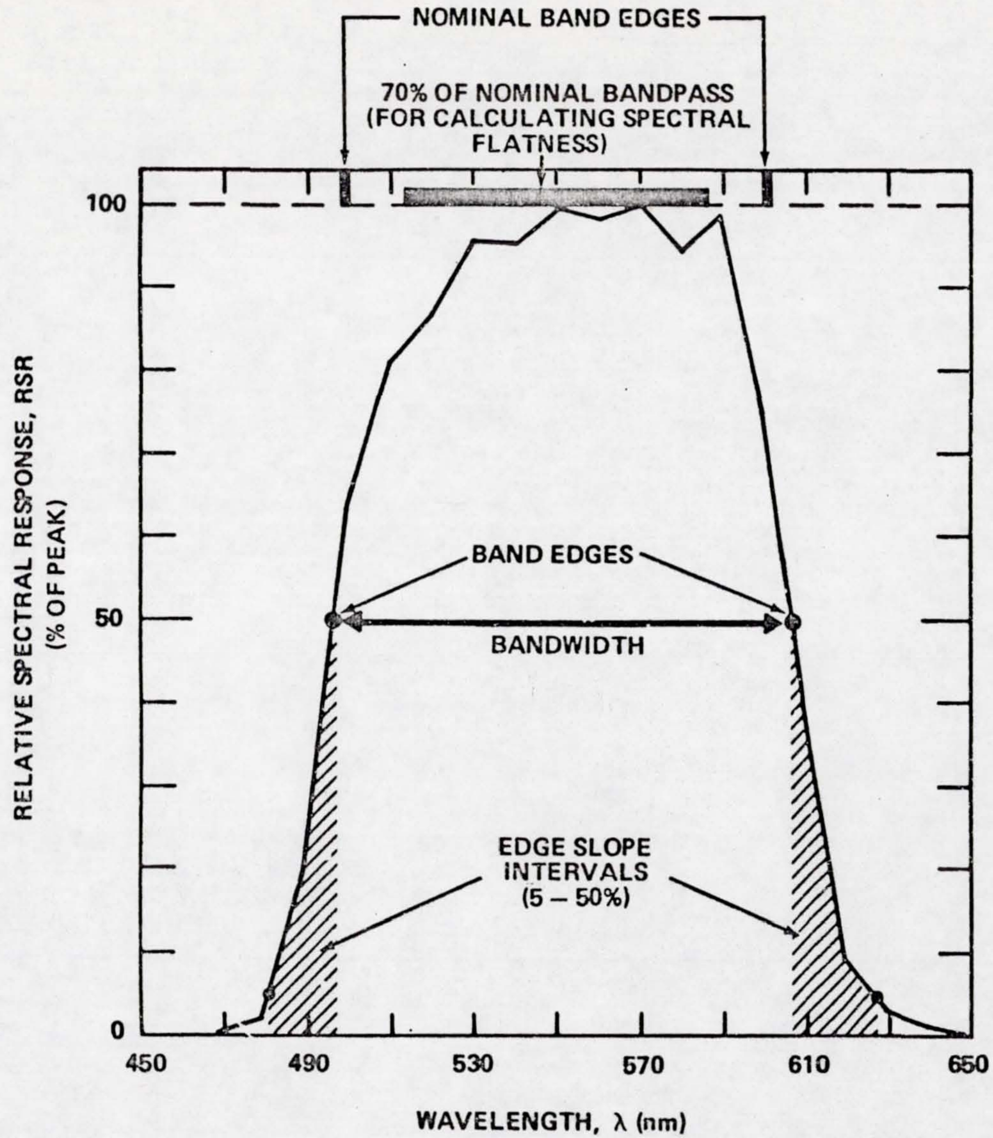
ESTIMATE THE ACCURACY AND PRECISION OF RADIOMETRIC CALIBRATIONS

245-N12-(41)

FILTER SPECIFICATIONS FOR LANDSAT MULTISPECTRAL SCANNERS

BAND	BAND EDGE (nm) HALF POWER POINTS		BAND WIDTH	SLOPE INTERVAL (nm) FROM 5% TO 50%		SPECTRAL FLATNESS (%) OVER CENTRAL 70%	
	LOWER	UPPER	(nm)	LOWER	UPPER	POSITIVE	NEGATIVE
1	500 ± 10	600 ± 10	—	<20	<40	<5.0	<5.0
2	600 ± 10	700 ± 10	—	<20	<45	<7.5	<7.5
3	700 ± 10	800 ± 10	—	<20	<50	<5.0	<5.0
4	800 ± 10	1100[a] ± 10	—	<35	—	<5.0	<5.0

a — UPPER BAND EDGE NOT FILTER DETERMINED — FILTER SPECIFICATION NECESSARY FOR FLATNESS DETERMINATION



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KEY TO FIGURES 2 AND 3

MSS-D SPECTRAL CHARACTERIZATION BY CHANNEL: BAND 2 (600-700 nm)

SCANNER	CHANNEL	BAND EDGE (nm) LOWER	BAND EDGE (nm) UPPER	WIDTH[a] (nm)	SLOPE INTERVAL (nm) LOWER	SLOPE INTERVAL (nm) UPPER	SPECTRAL FLATNESS POSITIVE	SPECTRAL FLATNESS NEGATIVE
PROTO-FLIGHT	7	603	708*	105*	12	19	8.2[b]	17.2[b]
	8	602	696	94	12	16	6.4	11.6[b]
	9	603	696	92	12	14	6.6	11.0[b]
	10	603	696	94	12	18	7.8[b]	11.1[b]
	11	604	698	94	13	17	4.5	11.7[b]
	12	602	695	93	12	15	8.2[b]	14.5[b]
FLIGHT	7	603	697	94	13	17	6.9	9.6[b]
	8	603	696	93	13	16	7.3	10.4[b]
	9	603	696	94	12	16	9.1[b]	13.3[b]
	10	602	696	93	12	14	9.1[b]	16.0[b]
	11	603	697	94	12	15	7.0	8.6[b]
	12	603	697	94	12	15	6.4	8.5[b]

a — NO FILTER SPECIFICATION

b — FAILS TO MEET FILTER SPECIFICATION

* —REJECTABLE AS OUTLIER: $\alpha = 0.01$

BAND 2 (600-700nm) SPECTRAL CHARACTERIZATION BY MEANS AND STANDARD DEVIATIONS: MSS 1, 2, 3, PF, F

	SCANNER	BAND EDGE (nm) LOWER	BAND EDGE (nm) UPPER	WIDTH[a] (nm)	SLOPE INTERVAL (nm) LOWER	SLOPE INTERVAL (nm) UPPER	SPECTRAL FLATNESS POSITIVE	SPECTRAL FLATNESS NEGATIVE
MEANS	PF*	603	698	95	12	$\boxed{16}$	7.0	12.9[b]
	PF**	603	$\boxed{696}$	93	12	$\boxed{16}$	6.7	12.0[b]
	F	603	$\boxed{697}$	94	12	$\boxed{15}$	7.6[b]	11.1[b]
	1	603	701	97	15	26	9.0[b]	13.3[b]
	2*	607	710	103	14	30	7.9[b]	18.0[b]
	2**	607	710	103	14	29	7.8[b]	16.8[b]
	3	606	705	100	14	31	7.2	17.2[b]
STANDARD DEVIATIONS	PF*	0.7	$\boxed{4.7}$	$\boxed{4.8}$	0.5	1.9	1.4	2.5
	PF**	0.8	0.8	0.6	0.5	1.4	1.5	1.4
	F	0.4	0.6	0.5	0.4	0.9	1.2	3.0
	1	3.5	2.2	2.8	1.7	3.4	3.4	2.8
	2*	0.6	0.8	1.0	1.2	3.6	1.1	4.5
	2**	0.6	0.9	1.1	1.2	1.0	1.2	3.8
	3	0.9	1.2	0.8	0.8	2.0	2.0	4.8

*WITH OUTLIER CHANNEL INCLUDED
**WITH OUTLIER CHANNEL EXCLUDED

a — NO FILTER SPECIFICATION
b — FAILS TO MEET FILTER SPECIFICATION

BOXES INDICATE CHARACTERISTICS WHERE DIFFERENCES BETWEEN PF OR F AND ALL PREVIOUS SCANNERS (1,2,3) WERE GREATER THAN DIFFERENCES BETWEEN TWO SETS OF PF MEASUREMENTS.

SIMULATED MSS BAND MEANS

TARGET	SENSOR SYSTEM	BAND 1[b]	BAND 2[b]	BAND 3[b]	BAND 4[b]
		MEANS[a] (DIGITAL MSS COUNTS)			
SOYBEANS	LSD-PF	19.36	14.89 (14.76)[c]	80.82*	45.80
	LSD-F	19.25	14.72	82.81*	45.39
	LS1	19.46 (19.55)[c]	15.43	76.95	47.14
	LS2	19.58	16.24 (16.13)[c]	78.58	47.24
	LS3	19.77	15.36	73.93	47.55
SOIL	LSD-PF	28.39	34.75[d]	41.02	18.61
	LSD-F	28.39	34.75	41.05	18.48
	LS1	28.32[d]	34.73	41.04	19.02
	LS2	28.34	34.66[d]	41.05	19.07
	LS3	28.33	34.66	41.10	19.15

a — AT SATELLITE SENSOR RESPONSE, NADIR—LOOKING FOR 40° SOLAR ZENITH ANGLE AND 20 km VISIBILITY; UNITS ARE SIMULATED NON-TRUNCATED MSS DIGITAL COUNTS WITH MAXIMUM SPECIFIED RADIANCE SCALED TO 127.99 FOR BANDS 1, 2, 3 AND 63.99 FOR BAND 4.

b — LANDSAT-D BANDS 1, 2, 3 AND 4 CORRESPOND TO BANDS 4, 5, 6 AND 7, RESPECTIVELY ON PREVIOUS LANDSATS.

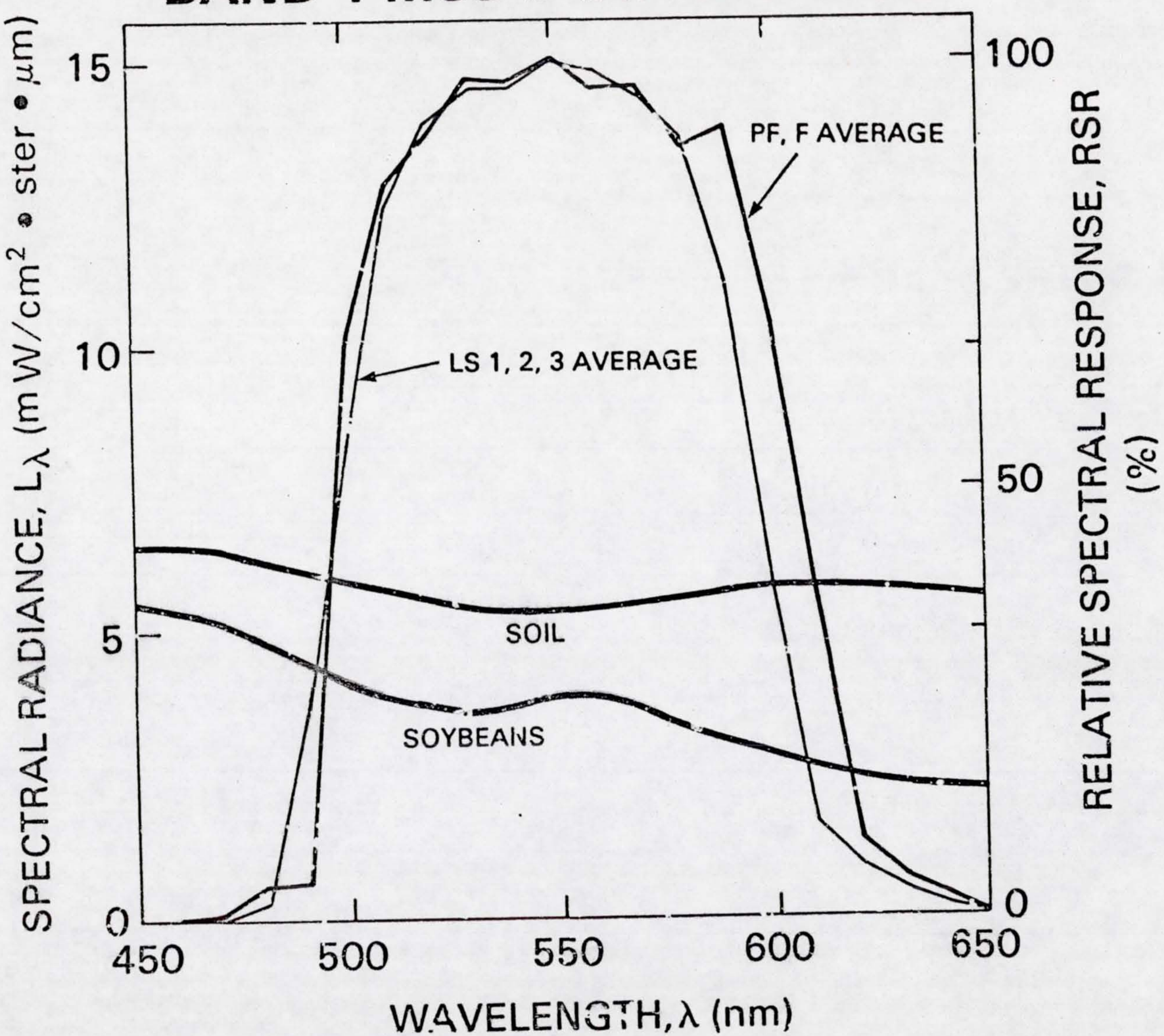
c — MEAN IN PARENTHESES IS WITH OUTLIER CHANNEL EXCLUDED

d — EXCLUSION OF OUTLIER DID NOT CHANGE BAND MEAN

*PF, F DIFFERENCE EXCEEDS: (1) DIFFERENCE BETWEEN SIMULATIONS RUN WITH EACH SET OF PF MEASUREMENTS SEPARATELY AND (2) 0.30 DIGITAL COUNTS

BOXES INDICATE BANDS WHERE OUTPUT DIFFERENCES BETWEEN PF OR F AND ALL PREVIOUS SCANNERS (1,2,3) EXCEED: (1) AND (2) AS ABOVE.

BAND 1 MSS-D DIFFERENCES



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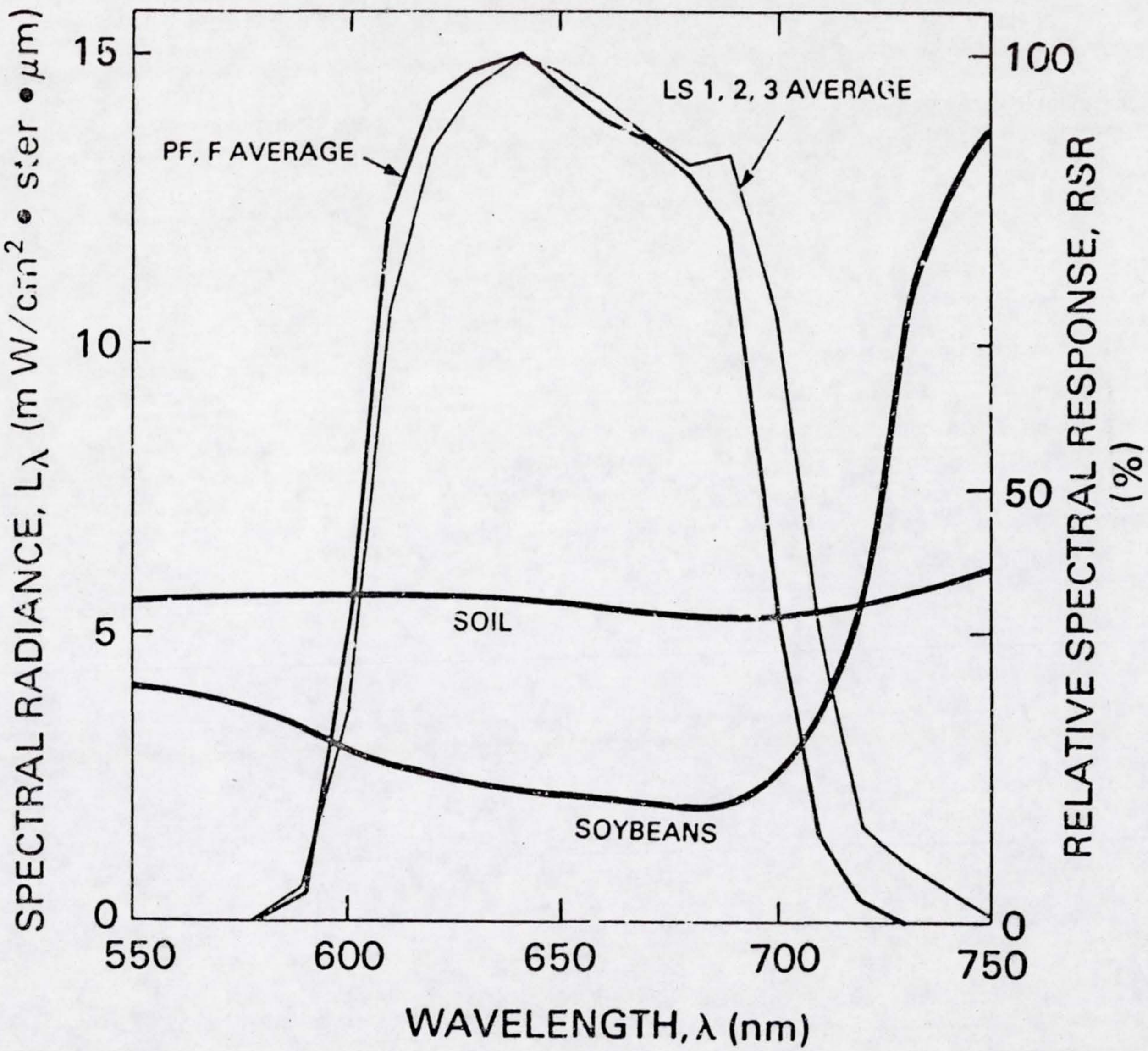
BAND 2 MSS-D DIFFERENCES



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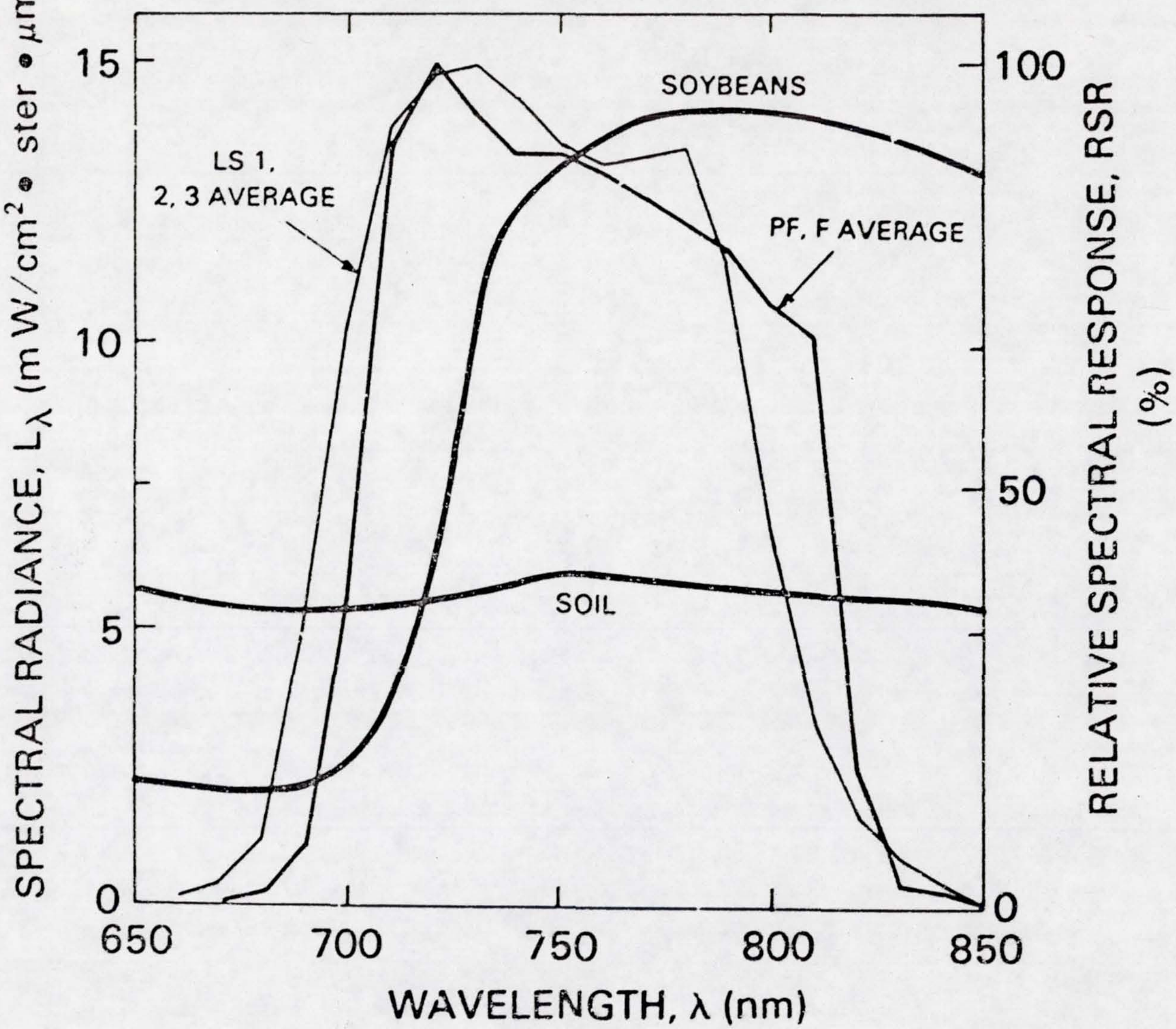
BAND 3 MSS-D DIFFERENCES



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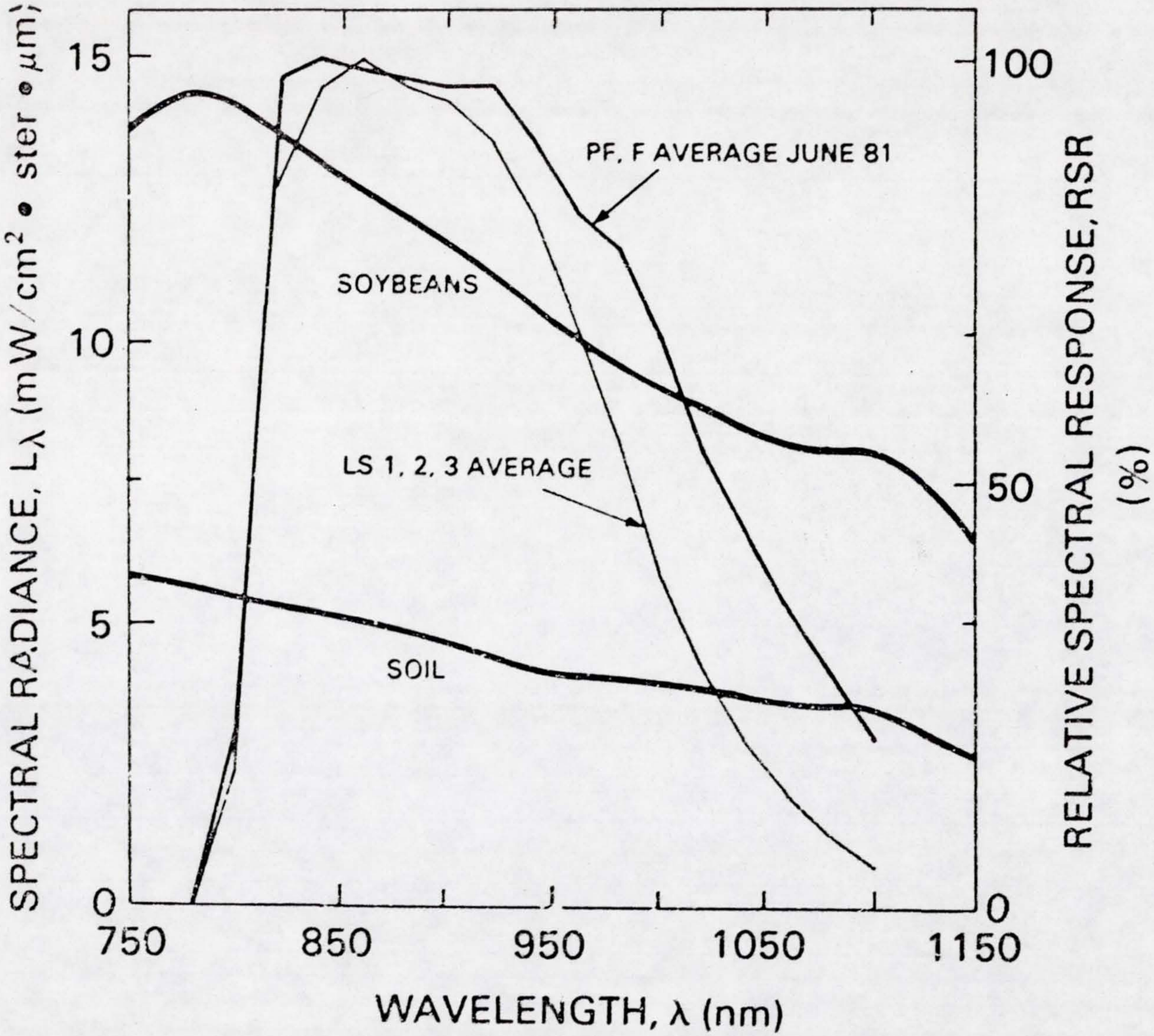
BAND 4 MSS-D APPARENT DIFFERENCES



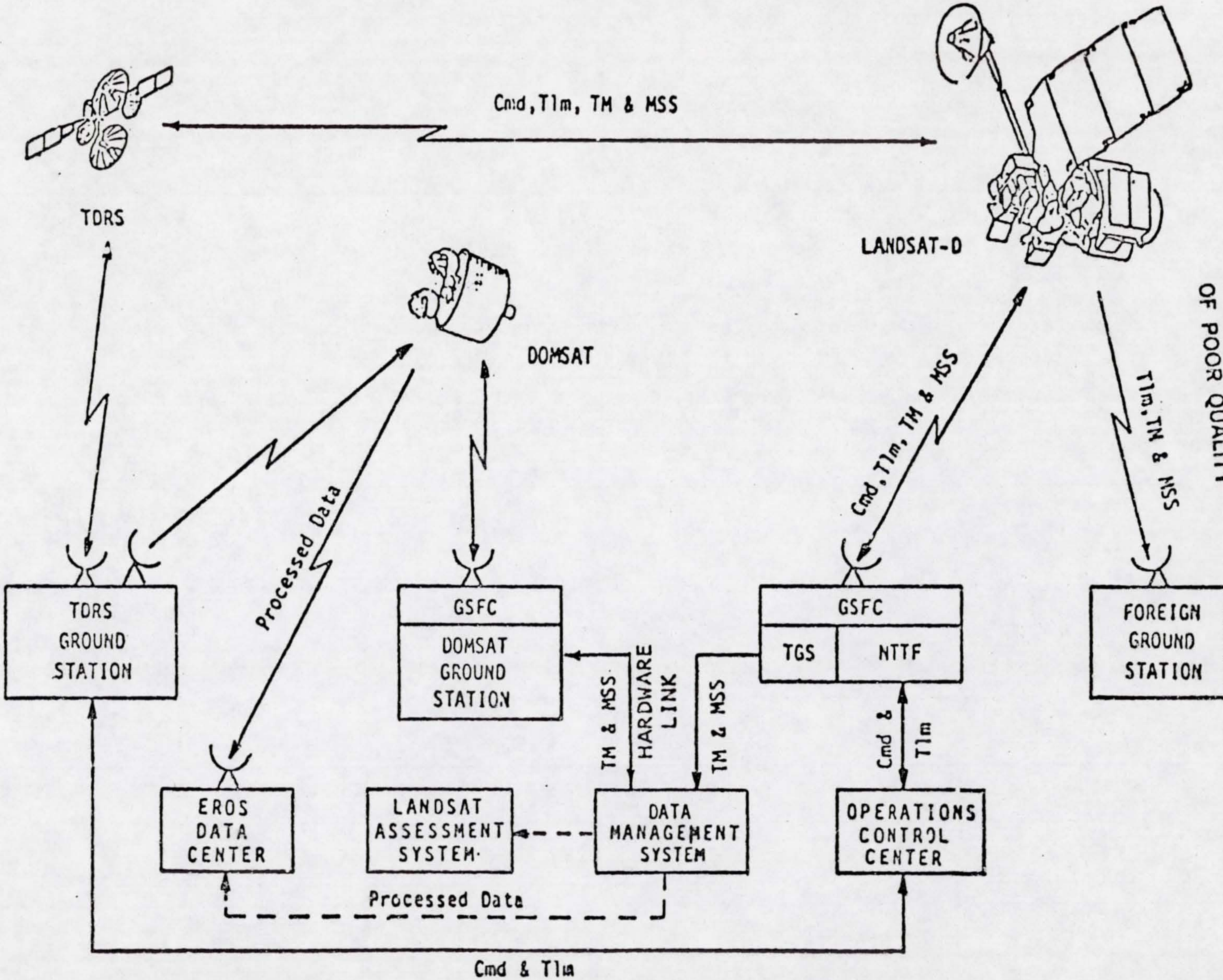
SIMULATED MAXIMUM WITHIN-BAND SENSOR OUTPUT DIFFERENCES

		DIGITAL COUNTS				PERCENT			
TARGET	SENSOR	BAND 1	BAND 2	BAND 3	BAND 4	BAND 1	BAND 2	BAND 3	BAND 4
SOYBEANS	LSD-PF	0.11	0.91•	2.23•	$\boxed{1.43^{\bullet}}$	0.6	6.2	2.8	3.1
	LSD-F	0.17	0.10•	$\boxed{0.78^{\bullet}}$	1.04•	0.9	0.7	0.9	2.3
	LS1	0.75	0.12	2.39	0.63	3.9	0.8	3.1	1.3
	LS2	0.16	0.77	3.63	0.39	0.8	4.8	4.6	0.8
	LS3	0.30	0.16	4.01	0.80	1.5	1.0	5.4	1.7
SOIL	LSD-PF	0.03	0.07	0.10	0.46	0.1	0.2	0.2	2.5
	LSD-F	0.01	0.05	0.02	0.32	0.1	0.2	0.1	1.8
	LS1	0.10	0.09	0.04	0.21	0.3	0.3	0.1	1.1
	LS2	0.05	0.03	0.06	0.12	0.2	0.1	0.2	0.6
	LS3	0.07	0.09	0.13	0.26	0.2	0.3	0.3	1.4

• PF, F DIFFERENCE EXCEEDS: (1) DIFFERENCE BETWEEN SIMULATIONS RUN WITH EACH SET OF PF MEASUREMENTS SEPARATELY AND (2) 0.30 DIGITAL COUNTS

BOXES INDICATE BANDS WHERE OUTPUT DIFFERENCES BETWEEN PF OR F AND ALL PREVIOUS SCANNERS EXCEED (1) AND (2) AS ABOVE

Landsat-D System Overview



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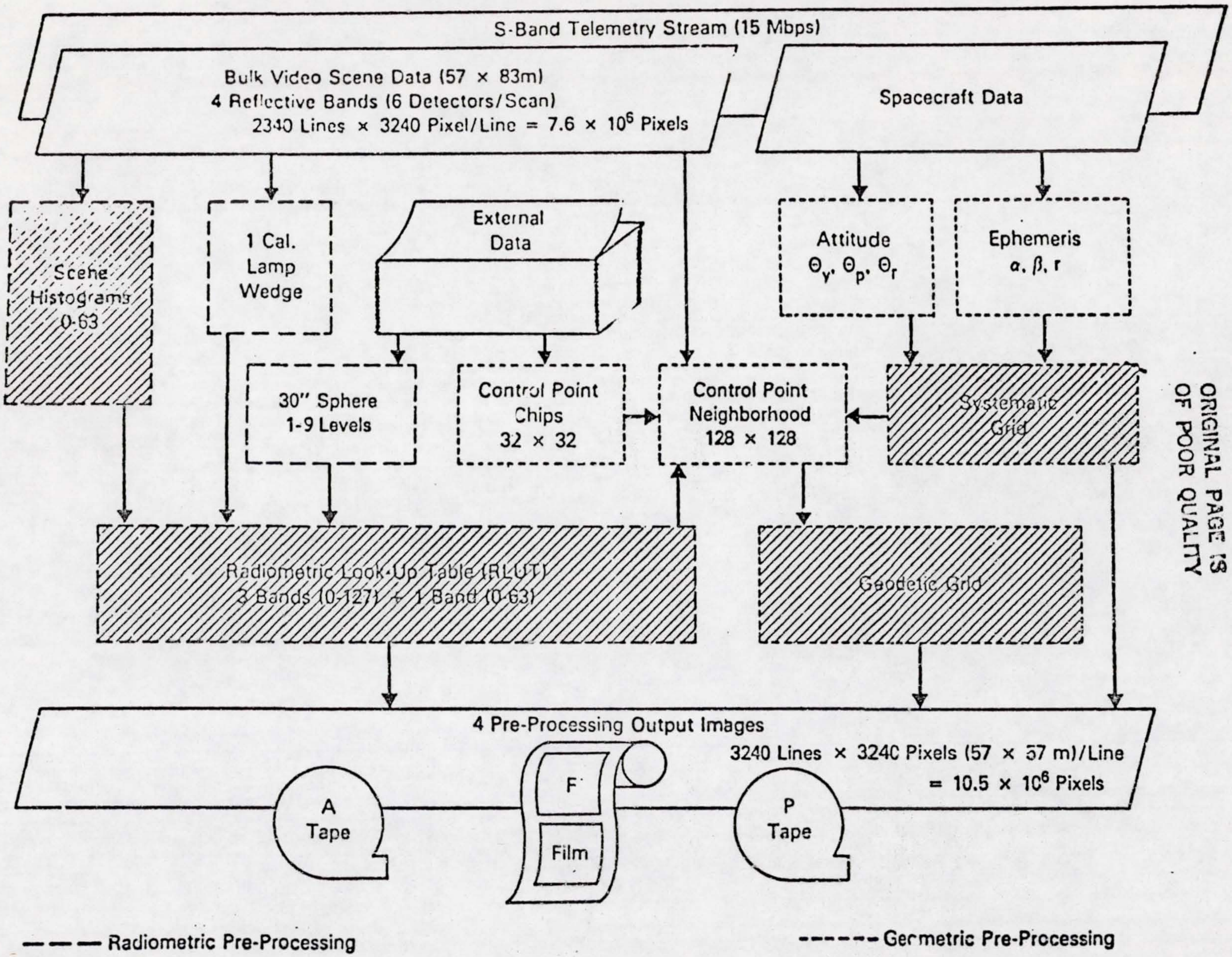
MSS Landsat-D Preprocessing



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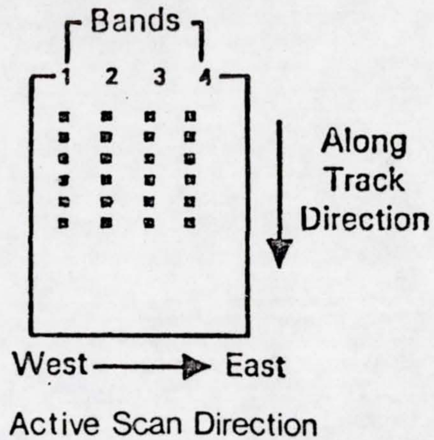
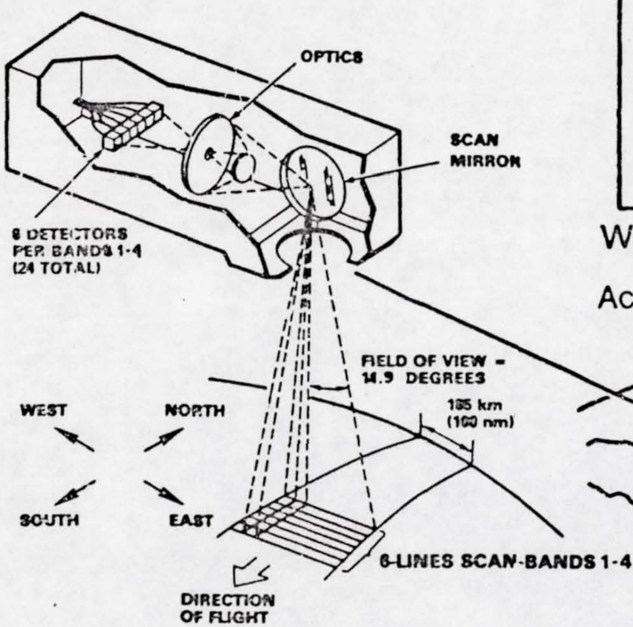
Landsat-D Protoflight Multispectral Scanner (MSS)

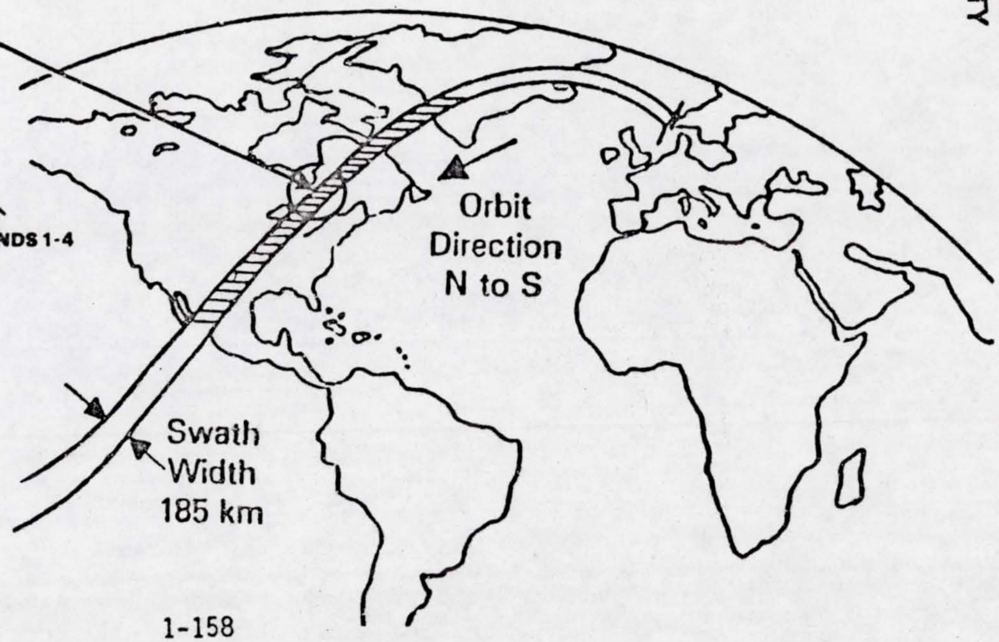
MSS Detector Details



Band	Spectral Ranges nm
1	495 - 605
2	603 - 698
3	701 - 813
4	808 - 1023

MSS SCANNING ARRANGEMENT





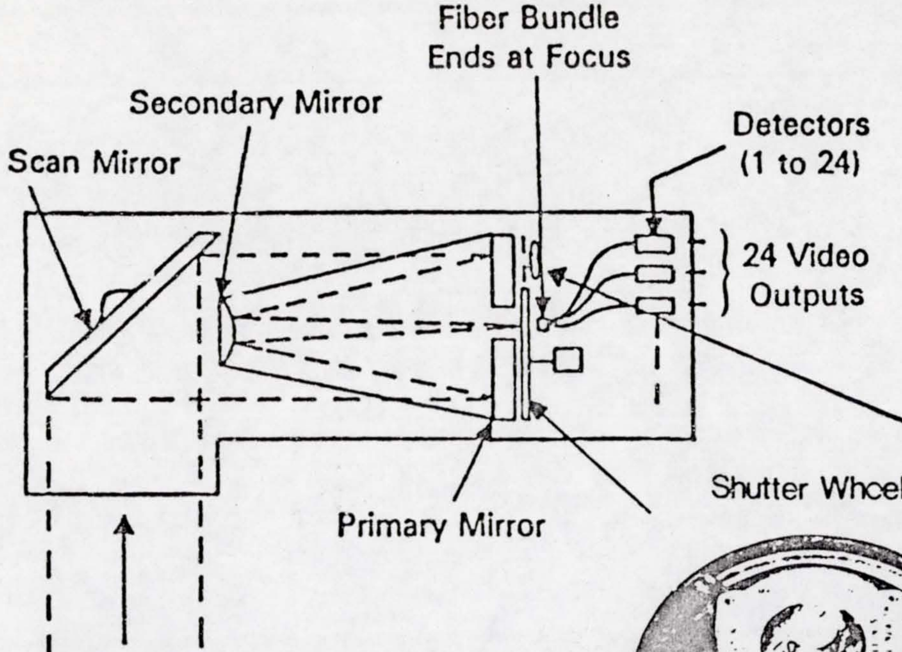
Ground IFOV

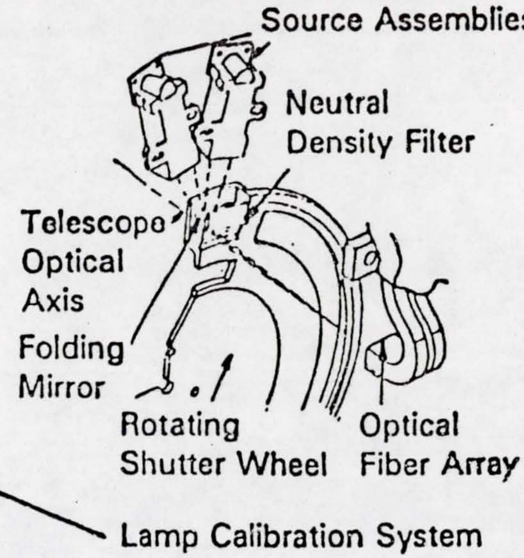
All Bands — 82.7 x 57m

Data Rate — 15.06 Mbps

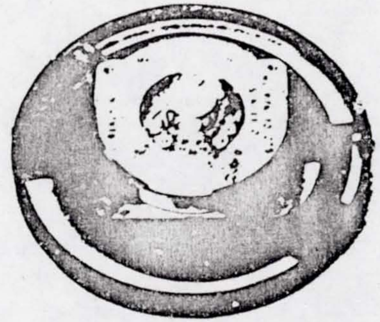
Quantization Levels — 64

Landsat MSS Absolute Radiometric Calibration

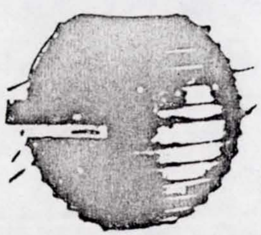




Shutter Wheel



Know Radiance



Integrating
Sphere

MSS CALIBRATION: DEFINITION OF VARIABLES

$\hat{R}_{JK}$ = INTEGRATING SPHERE RADIANCE FOR SPHERE LEVEL J AND MSS CHANNEL K

$$R_{JK} = BW_K \frac{\int RW_J \; RSR_K \, d\lambda}{\int RSR_K \, d\lambda}$$

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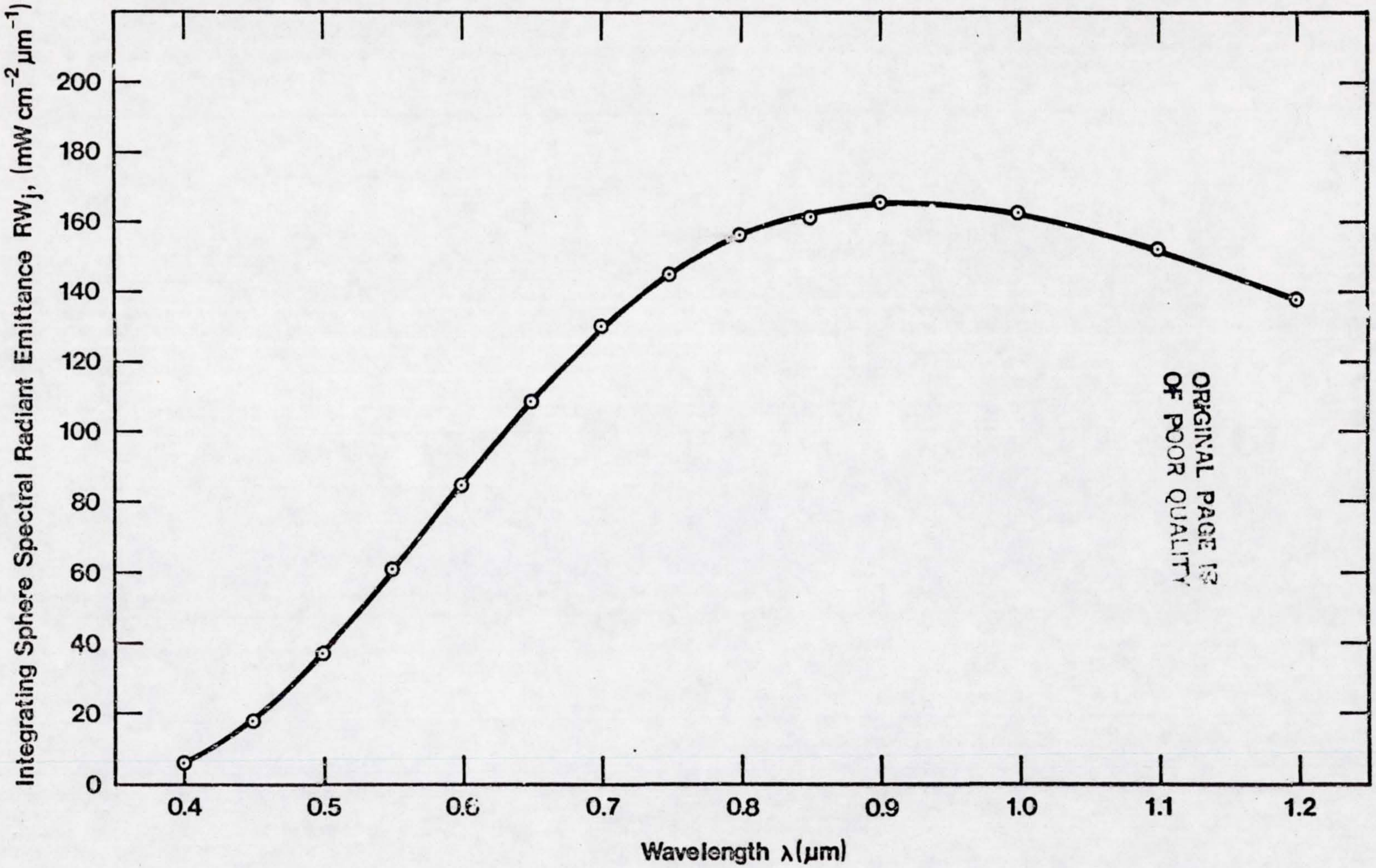
BW_K = MEASURED BANDWIDTH OF CHANNEL K

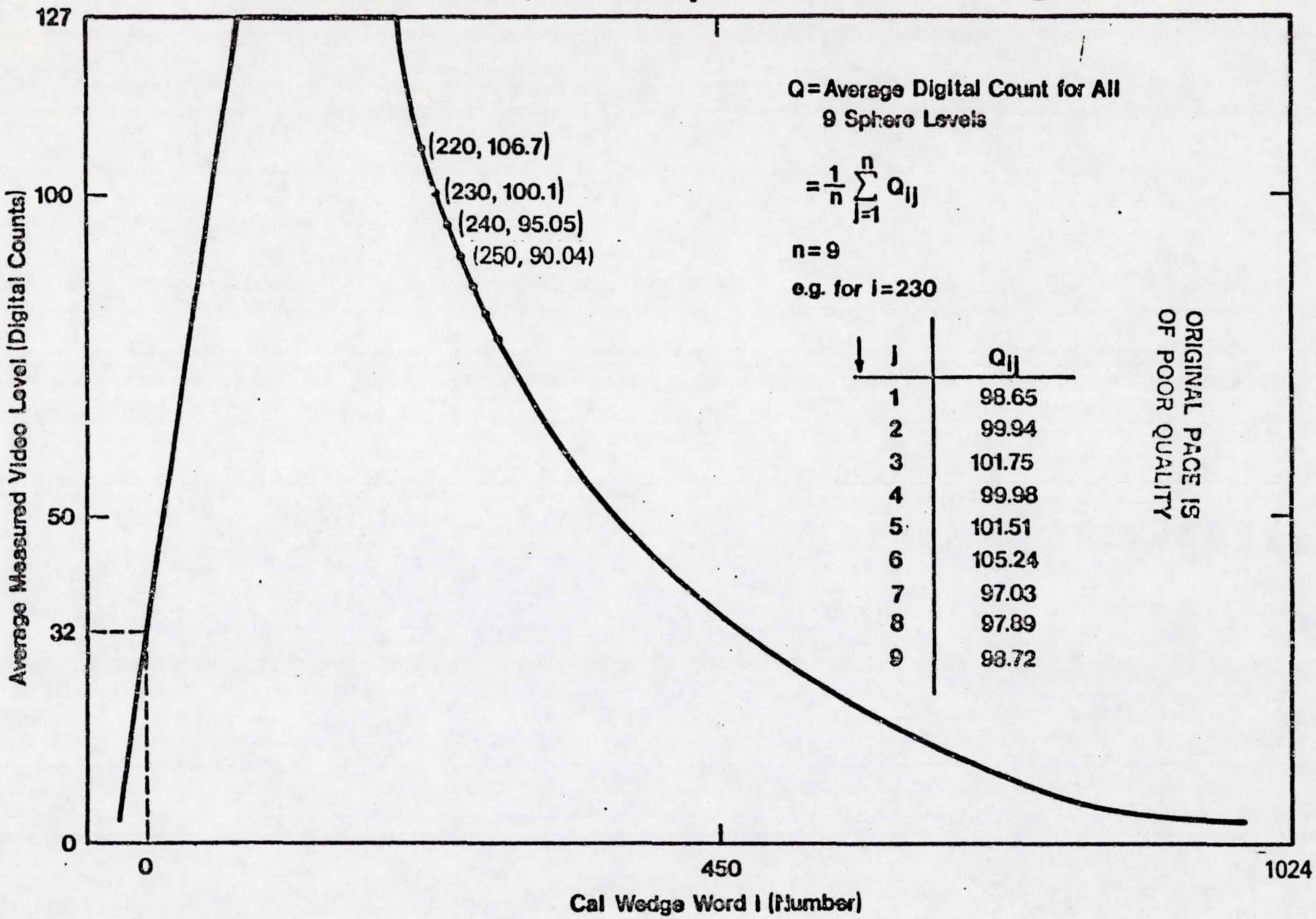
RSR_K = MEASURED RELATIVE SPECTRAL RESPONSE FOR CHANNEL K

RW_J = SPECTRAL RADIANCE FOR 76 CM INTEGRATING SHPHERE FOR SPHERE LEVEL J

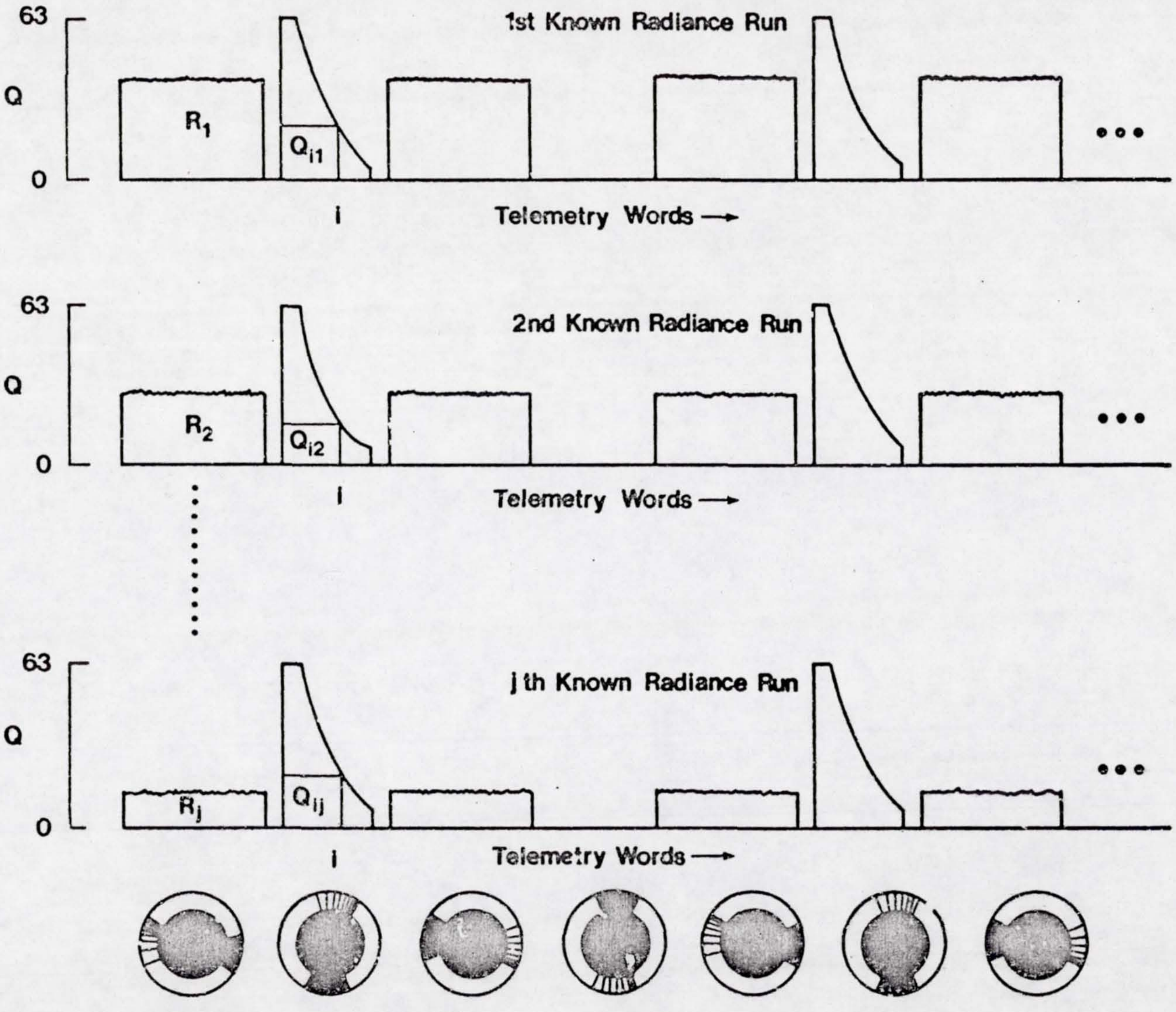
Spectral Radiant Emittance Plot for 76 cm Integrating Sphere



Illustrative MSS/PF Lamp Calibration Wedge



Systematic MSS Video and Wedge Level Timing Sequence



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MSS CALIBRATION: DEFINITION OF VARIABLES (CONT'D.)

V_J = SCENE AVERAGES VIDEO LEVEL FOR SPHERE LEVEL J

$$V_J = \frac{1}{390} \sum_{L=1}^{390} \frac{1}{N} \sum_{s=1}^{N} v_{JSL}$$

v_{JSL} = RAW VIDEO LEVEL IN DIGITAL COUNTS OF PIXEL s ON LINE L FOR SPHERE LEVEL J

s = INDEX FOR SUM OF PIXELS IN A LINE

L = INDEX FOR SUM OF LINES IN A SCENE

Q_{IJ} = AVERAGE WEDGE LEVEL AT WORD I AFTER SPHERE LEVEL J

$$Q_{IJ} = \frac{1}{390} \sum_{L=1}^{390} q_{IJL}$$

q_{IJL} = RAW DIGITAL COUNTS FOR WEDGE WORD I ON LINE L AFTER SPHERE LEVEL J

I = WORD NUMBER

J = SPHERE RADIANCE LEVEL

L = LINE NUMBER

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MSS/PF ILLUSTRATIVE ABSOLUTE CALIBRATION TRANSFER
FROM SPHERE TO CALIBRATION LAMP WEDGE WORD (230)
FOR BAND 1, CHANNEL 1
(15TH SEPT., 1981, AT GE, VALLEY FORGE)

INTEGRATING SPHERE RADIANCE LEVEL R_J ($mW\ cm^{-2}\ sr^{-1}$)	AVERAGED VIDEO LEVEL V_J (DIGITAL COUNTS)	AVERAGED WEDGE LEVEL (390 SCANS) Q_{IJ} (DIGITAL COUNTS)
.04	2.1	97.03
.09	3.5	97.89
.12	5.5	98.72
.17	7.7	98.65
.33	15.4	99.94
.48	22.2	101.75
.64	29.4	99.98
.96	46.6	101.51
1.95	96.6	105.24

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$$\bar{Q}_I = \frac{1}{9}\sum_{J=1}^{9} Q_{IJ} = 100.08$$

ILLUSTRATES HYSTERESIS DEPENDENCE OF WEDGE VALUE ON PRECEDING RADIANCE LEVEL

CORRECTION PROCEDURE FOR HYSTERESIS EFFECT

- MODEL EXPECTED CAL WEDGE VALUE FOR WORD i AFTER SPHERE LEVEL J AS A FUNCTION OF AVERAGE VALUE FOR ALL SPHERE LEVELS

$$Q_{IJ} = A_J + B_J \bar{Q}_I$$

- ADJUST VIDEO VALUE FOR SPHERE LEVEL J ASSUMING THE HYSTERESIS TIME CONSTANT IS LONG RELATIVE TO THE 73 MSEC SCAN TIME

$$V_J = A_J + B_J VA_J$$

$$VA_J = \frac{V_J - A_J}{B_J}$$

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LINEAR HYSTERESIS MODEL FOR LAMP CALIBRATION WEDGE VALUES FOR MSS/PF BAND 1, CHANNEL 1

I	$\bar{Q}_I$ (DIGITAL COUNTS)	Q_{IJ} (DIGITAL COUNTS)
220	106.7	112.9
230	100.1	105.2
240	95.1	99.7
250	90.0	94.6
260	85.7	90.7
270	81.3	85.9
280	77.5	81.6
290	73.0	77.1
300	68.9	73.2
310	65.5	68.7
810	4.1	4.3
820	3.9	4.1
850	3.2	3.3
860	3.0	3.2

LEAST SQUARES FIT TO

$$Q_{IJ} = A_J + B_J \bar{Q}_I$$

FOR BRIGHTEST SPHERE LEVEL J WITH

$R_J = 1.95$ mW $cm^{-2} sr^{-1}$

HYSTERESIS OFFSET

$A_J = .02$

HYSTERESIS GAIN

$B_J = 1.054$

$R^2 = .99996$

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ADJUSTMENT OF SPHERE VIDEO LEVELS FOR
HYSTERESIS EFFECT FOR MSS/PF BAND 1, CHANNEL 1

AVERAGED VIDEO VALUE FOR INTEGRATING SPHERE LEVEL J V_J (DIGITAL COUNTS)	LINEAR REGRESSION COEFFS $Q_{IJ} = A_J + B_J \bar{Q}_I$ A_J	B_J	ADJUSTED VIDEO LEVEL $VA_J = \frac{V_J - A_J}{B_J}$ (DIGITAL COUNTS)	SPHERE RADIANCE R_J ($mWcm^{-2}sr^{-1}$)
2.1	.01	.971	2.15	.04
3.5	-.08	.980	3.65	.09
5.5	-.01	.984	5.60	.12
7.7	.00	.986	7.81	.17
15.4	.00	1.000	15.39	.33
22.2	.01	1.014	21.89	.48
29.4	.03	.997	29.47	.64
46.6	.01	1.014	45.96	.96
96.6	.02	1.054	91.61	1.95

CALIBRATION PROCEDURE FOR LAMP RADIANCE
TRANSFER OF SPHERE RADIANCE TO DETECTOR VIDEO
VALUE

LEAST SQUARES FIT: $VA_J = p + qR_J$

MSS/PF BAND 1, CHANNEL 1, SPHERE TO DETECTOR

OFFSET $p = -.21$ (DIGITAL COUNTS)

GAIN $q = 47.17$ (DIGITAL COUNTS/$mWcm^{-2}sr^{-1}$)

ASSUME LAMP RADIANCE CAN BE CALCULATED FROM p, q

$$\overline{Q_I} = p + qR_I$$

$$R_I = \frac{\bar{Q}_I - p}{q}$$

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CALCULATION OF LAMP RADIANCE FOR SIX OPERATIONAL WEDGE WORDS FOR MSS/PF BAND 1, CHANNEL 1

WEDGE WORD NUMBER	OBSERVED AVERAGE WEDGE LEVEL	CALCULATED RADIANCE FOR WEDGE WORD
I	$\bar{Q}_I$	$R_I = \frac{\bar{Q}_I - p}{q}$
	(DIGITAL COUNTS)	($mWcm^{-2}sr^{-1}$)
230	100.08	2.126
240	95.05	2.020
250	90.04	1.913
260	85.67	1.821
810	4.07	.091
820	3.85	.086

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CALCULATION OF LAMP RADIANCE FOR SIX OPERATIONAL
WEDGE WORDS FOR MSS/PF BAND 1, CHANNEL 1

WEDGE WORD NUMBER	OBSERVED AVERAGE WEDGE LEVEL	CALCULATED RADIANCE FOR WEDGE WORD
I	$\bar{Q}_I$	$R_I = \frac{\bar{Q}_I - p}{q}$
	(DIGITAL COUNTS)	($mWcm^{-2}sr^{-1}$)
230	100.08	2.126
240	95.05	2.020
250	90.04	1.913
260	85.67	1.821
810	4.07	.091
820	3.85	.086

INTERNAL LAMP RADIANCE VALUES FOR SIX
CALIBRATION WORD LOCATIONS FOR MSS/PF
BAND 1

CHANNEL	230	240	250	260	810	820
1	2.126	2.020	1.913	1.821	.091	.086
2	2.056	1.952	1.857	1.763	.085	.081
3	2.099	1.992	1.899	1.808	.089	.084
4	2.047	1.944	1.849	1.760	.086	.080
5	2.062	1.966	1.854	1.766	.089	.083
6	2.058	1.950	1.856	1.770	.087	.082

CALCULATION OF GAIN AND OFFSET USING LAMP RADIANCE VALUES AT SIX OPERATIONAL WEDGE WORDS

LINEAR REGRESSION: $\bar{Q}_I = \alpha + \beta R_I$

CHANNEL OFFSET $= \alpha = \sum_{I=1}^{6} C_I \bar{Q}_I$

CHANNEL GAIN $= \beta = \sum_{I=1}^{6} D_I \bar{Q}_I$

<u>CALIBRATION REGRESSION COEFFICIENTS</u>:

$$C_I = \left[\sum R_I^2 - R_I \sum R_I\right] / K$$

$$D_I = \left[6R_I - \sum R_I\right] / K$$

$$K = 6\sum R_I^2 - \left(\sum R_I\right)^2$$

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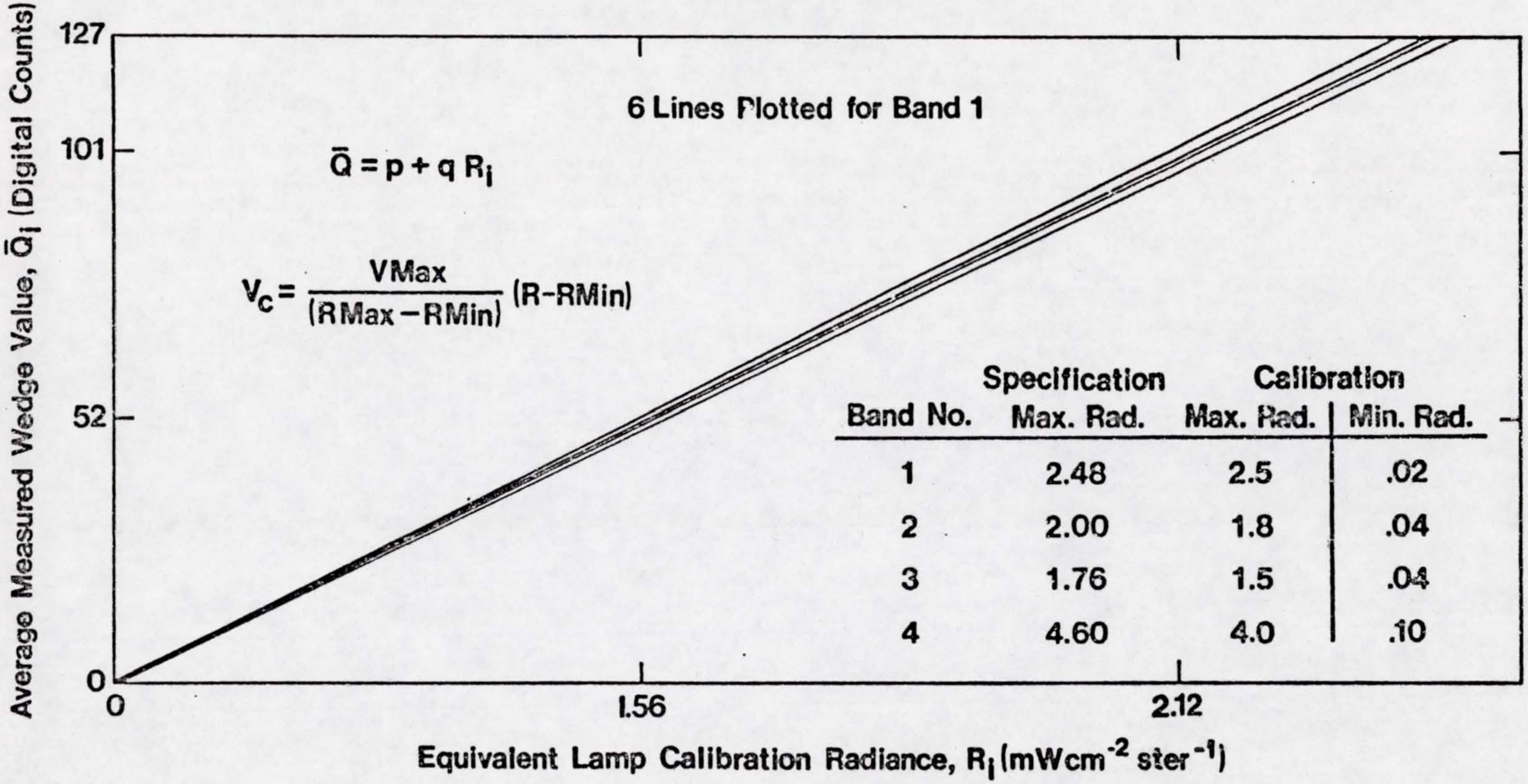
BAND NORMALIZATION OF MSS CHANNEL GAINS AND OFFSETS



	Specification	Calibration	
Band No.	Max. Rad.	Max. Rad.	Min. Rad.
1	2.48	2.5	.02
2	2.00	1.8	.04
3	1.76	1.5	.04
4	4.60	4.0	.10

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ILLUSTRATIVE MSS/PF LINEAR REGRESSION COEFFICIENTS FOR BAND 1

WORD 230		WORD 240		WORD 250		WORD 260		WORD 810		WORD 820	
D_1	C_1	D_2	C_2	D_3	C_3	D_4	C_4	D_5	C_5	D_6	C_6
.1641	-.054	.1418	-.024	.1195	.006	.1002	.032	-.2624	.519	-.2633	.520
.1689	-.053	-1457	-.023	.1244	.005	.1035	.032	-.2707	.518	-.2718	.520
.1648	-.052	.1420	-.022	.1220	.005	.1026	.030	-.2651	.519	-.2662	.520
.1691	-.052	.1461	-.022	.1247	.005	.1048	.031	-.2717	.518	-.2730	.520
.1688	-.053	.1474	-.025	.1225	.007	.1029	.033	-.2700	.519	-.2716	.521
.1690	-.053	.1450	-.022	.1240	.005	.1047	.031	-.1707	.519	-.2720	.520

BAND NORMALIZED EQUATIONS

BAND NORMALIZED CHANNEL OFFSET $\alpha' \equiv \sum C'_I \ \bar{Q}_I \equiv B$ = CHANNEL BIAS

BAND NORMALIZED CHANNEL GAIN $\beta' \equiv \sum D'_I \ \bar{Q}_I \equiv G$ = CHANNEL GAIN

WHERE BAND NORMALIZED REGRESSION COEFFICIENTS

$$C'_I = C_I + R_{MIN} D_I$$

$$D'_I = \left(R_{MAX} - R_{MIN}\right) D_I$$

BAND NORMALIZED VIDEO VALUE, VB, IS:

$$VB = \frac{127}{\beta'} (V - \alpha')$$

WHERE V IS THE RAW DIGITAL VIDEO VALUE AND THIS IS THE DIMENSIONLESS ABSOLUTE CALIBRATION EQUATION

BAND NORMALIZED LINEAR REGRESSION COEFFICIENTS FOR MSS BAND 1

CHANNEL	D_1'	C_1'	D_2'	C_2'	D_3'	C_3'	D_4'	C_4'	D_5'	C_5'	D_6'	C_6'
1	.403	-.051	.352	-.021	.296	.008	.248	.034	-.652	.514	-.653	.515
2	.419	-.049	.361	-.020	.309	.008	.257	.034	-.671	.513	-.674	.514
3	.409	-.049	.352	-.019	.303	.007	.254	.032	-.657	.513	-.660	.515
4	.419	-.049	.362	-.019	.309	.008	.260	.033	-.674	.513	-.677	.515
5	.419	-.050	.366	-.022	.303	.009	.255	.035	-.670	.513	-.674	.515
6	.420	-.050	.360	-.019	.307	.008	.260	.033	-.671	.513	-.675	.515

MSS/PF ABSOLUTE RADIOMETRIC ACCURACY

CONCLUSIONS

- INTEGRATING SPHERE RADIANCE CORRECT TO 10% RELATIVE TO NBS STANDARD

- ERRORS FROM USE OF NOMINAL BAND WIDTHS (PRIOR TO RECALIBRATION BY GE)

BAND	RANGE OF RADIANCE ERROR	RADIANCE BIAS
1	1.8 %	- 9 %
2	12.9 %	7 %
3	2.6 %	-12 %
4	19.5 %	28 %

MSS RADIOMETRIC PRE-PROCESSING PROCEDURES

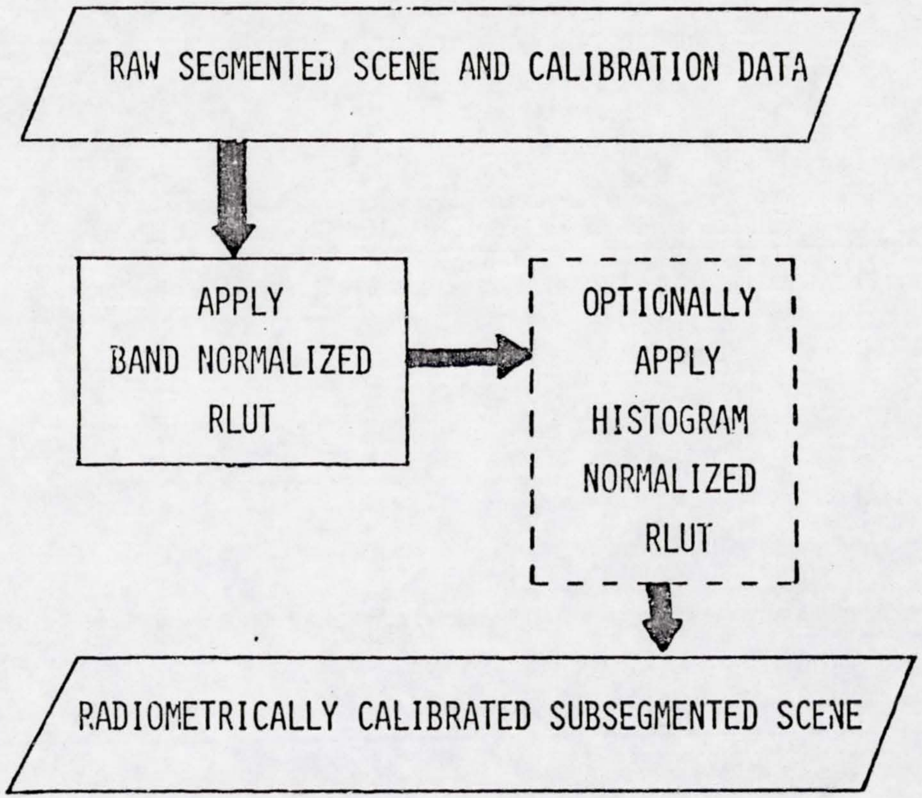
(MIPS = MSS IMAGE PROCESSING SYSTEM)

PURPOSE: CONVERT OBSERVED VIDEO DIGITAL COUNTS, V, INTO COUNTS WHICH ARE PROPORTIONAL TO RADIANCE, VA, BY USING RADIOMETRIC LOOK-UP TABLES (RLUTs)

STEPS:

- o COLLECT SCENE SEGMENT DATA
- o CALCULATE BAND NORMALIZED GAIN, BIAS, AND RESULTING RLUT BY SEGMENT USING INTERNAL CALIBRATION LAMP DATA
- o MODIFY GAIN AND BIAS USING SCENE HISTOGRAMS (OPTIONAL)
- o GENERATE RLUT FOR EACH SUBSEGMENT BY BLENDING SEGMENT-LEVEL GAIN AND BIAS

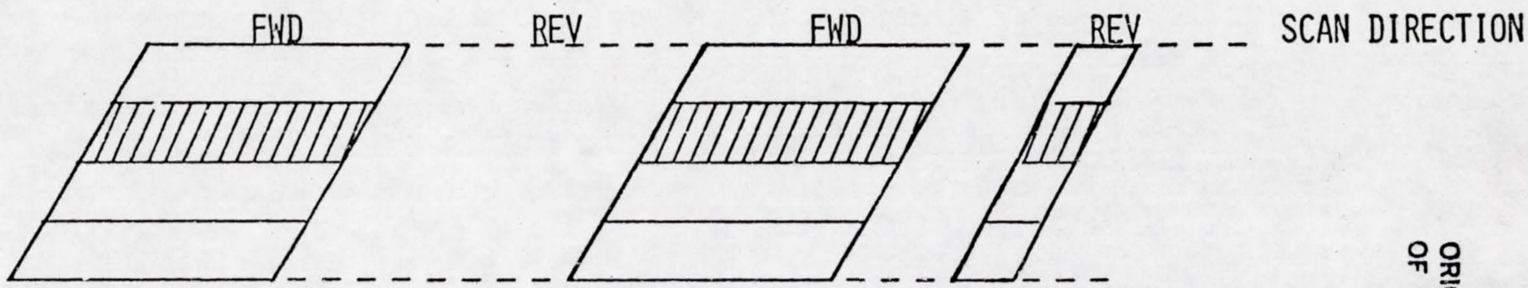
RADIOMETRIC PRE-PROCESSING DATA FLOW



COLLECT MSS SCENE SEGMENT DATA

DURING INITIAL INGEST OF RAW DATA INTO MIPS:

DIVIDE EACH SCENE INTO SEGMENTS (CAN BE ONE, TWO, FOUR, OR EIGHT)



SCENE SEGMENT	SCENE SEGMENT	CALIBRATION SEGMENT
DIGITAL VIDEO	DIGITAL VIDEO	DIGITAL WEDGE
V (0 - 63)	V (0 - 63)	Q (0 - 63)

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COLLECT SCENE HISTOGRAMS OF DIGITAL VIDEO VALUES, V, FOR EACH SEGMENT.

COLLECT SIX DIGITAL CALIBRATION WEDGE WORDS, Q, FROM EVERY OTHER LINE FOR EACH SEGMENT.

CALCULATE 24 BAND NORMALIZED RLUTs

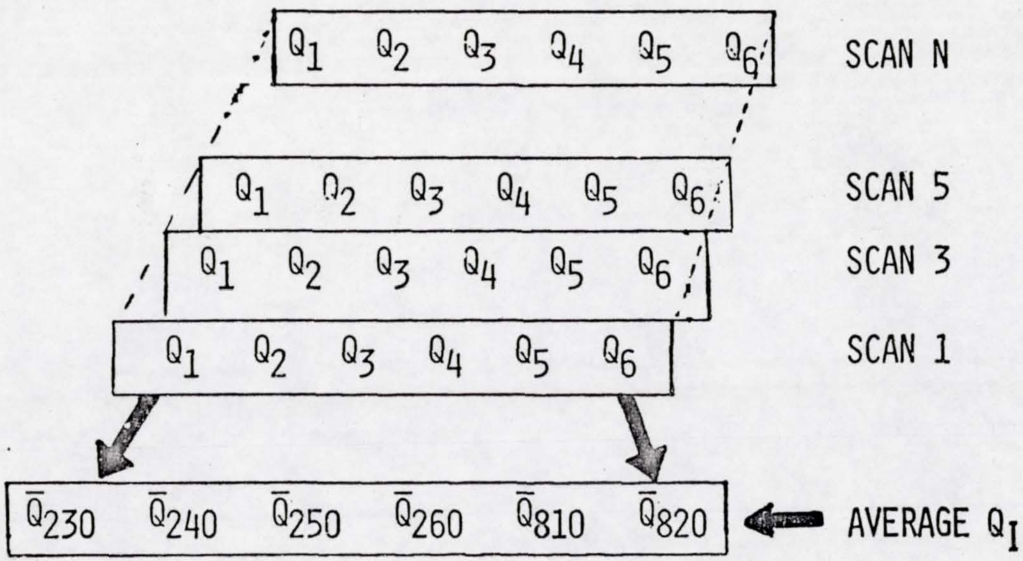
FOR EACH SEGMENT FROM SELECTED CALIBRATION WEDGE DATA

- CALCULATE SIX AVERAGE CALIBRATION WEDGE VALUES, $\bar{Q}$, FOR EACH CHANNEL
- CALCULATE INITIAL GAIN (G) AND BIAS (B) FOR EACH CHANNEL
- CALCULATE POST-LAUNCH MODIFIERS
- CALCULATE A BAND NORMALIZED RLUT BY CHANNEL

CALCULATE SIX AVERAGE CALIBRATION WEDGE VALUES FOR EACH CHANNEL IN THE SEGMENT

- DECOMPRESS THE SIX CALIBRATION WEDGE DIGITAL VALUES, Q, ACQUIRED ON EVERY OTHER SCAN, FROM (0 - 63) TO (0 - 127)

- CALCULATE AVERAGE CALIBRATION WEDGE VALUE, $\bar{Q}$, FOR EACH WORD



WORD NUMBER I	WORD LOCATION N_I
1	230
2	240
3	250
4	260
5	810
6	820

CALCULATE INITIAL GAIN (G) AND BIAS (B)

FOR EACH CHANNEL IN THE SEGMENT

RETRIEVE ABSOLUTE LAMP CALIBRATION LINEAR REGRESSION COEFFICIENTS, C' AND D' FROM DATA BASE

CALCULATE GAIN AND BIAS FOR EACH CHANNEL:

$$G = \sum C'\overline{Q}$$

$$B = \sum D'\overline{Q}$$

CALCULATE POST-LAUNCH MODIFIERS

(AS NECESSARY)

BASED ON HISTOGRAMING OF REAL SCENE DATA,

CALCULATE MODIFIER (M) AND ADDER (A) TERMS TO CORRECT FOR RESIDUAL STRIPING AND ATMOSPHERIC EFFECTS BY UPDATING THE ABSOLUTE CALIBRATION EQUATION TO:

$$VC = \frac{127}{MG} (V-B) - A \equiv G'V + B'$$

M = 1 AND A = 0 UNTIL TIME OF UPDATE

CALCULATE A BAND NORMALIZED RLUT
(FOR EACH CHANNEL)

COMPUTE A SEGMENT SPECIFIC RLUT:

$$RLUT = INTEGER \left[(i - 1) - B\right] /G$$

MAP RLUT INTO COMMON RANGE FROM 0 TO 127 TO AVOID STRIPING FROM DETECTORS WITH DIFFERENT SENSITIVITY

MODIFY BAND NORMALIZED GAIN AND BIAS USING SCENE HISTOGRAMS

FOR EACH CHANNEL IN THE SEGMENT

- o DECOMPRESS THE RAW SCENE HISTOGRAMS FROM (0 - 63) TO (0 - 127) (CONVERTS V-VALUES TO VD-VALUES IN ORDER TO CORRECT FOR NON-LINEARITY OF PHOTOMULTIPLIER TUBES)

- o CREATE CALIBRATED SCENE HISTOGRAMS BY APPLYING BAND NORMALIZED RLUT TO DECOMPRESSED SCENE HISTOGRAMS

- o CREATE A BAND AVERAGE SCENE HISTOGRAM FROM THE SIX INDIVIDUAL HISTOGRAMS

- o MODIFY EACH CHANNEL HISTOGRAM, RH, SO THAT IT HAS THE SAME MEAN, MEAN(RH), AND STANDARD DEVIATION, SD(RH), AS THE BAND AVERAGE HISTOGRAM, $\overline{RH}$, USING THE FOLLOWING FORMULA

HISTOGRAM NORMALIZATION (CONTINUED)

$$\overline{RH} = G*RH + b$$

$$g = SD(\overline{RH})/SD(RH)$$

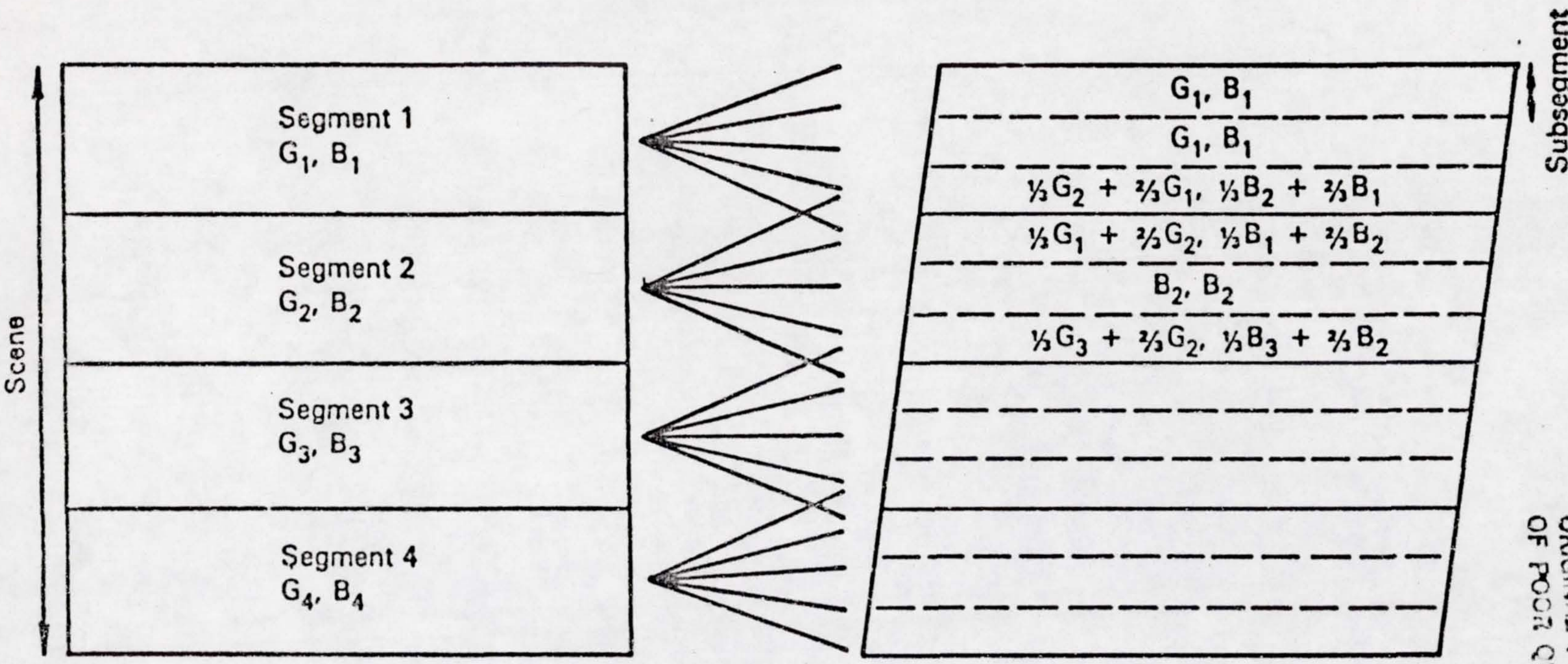
$$b = MEAN(\overline{RH}) - g*MEAN(RH)$$

CALCULATE A HISTOGRAM NORMALIZED GAIN, G'', AND BIAS, B''

$$G'' = G'/g$$

$$B'' = B - G'*b$$

Scene Segment Blending



Example of Segment Blending With Number
Of Segments = 4
Number of Sub-Segments/Segment = 3

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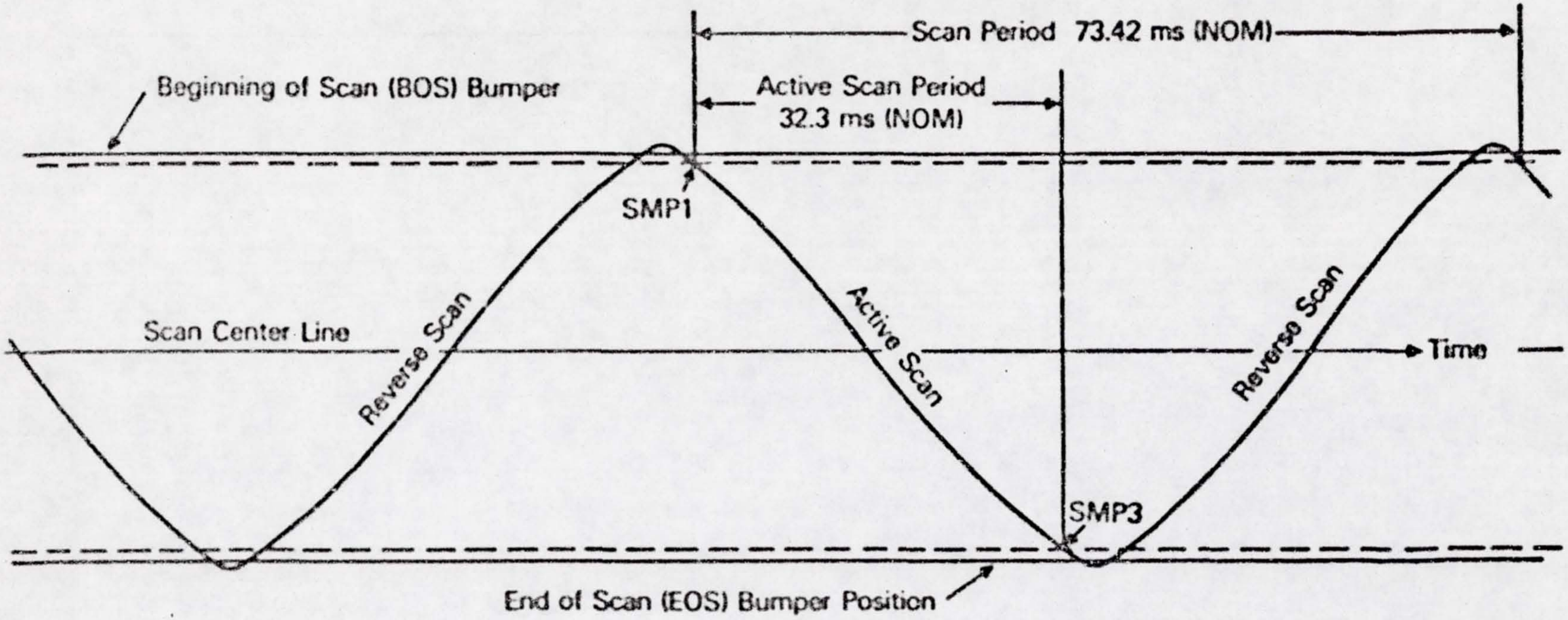
MSS Geometric Sensor Performance

Gary Banks

Protoflight MSS-D
Geometric Performance Summary

	SPEC	ACTUAL
Line Length Variation		
TM off	42 μrad (rms)	12-19 μrad (rms)
TM on	42 μrad (rms)	109-113 μrad (rms)
Line Length (Average)	31.5-34 ms	32.3 ms
Total Scan Angle	.26 ± .001 rad	.2603 rad
Scan Repeatability		
TM off	24 μrad (rms)	< 3 μrad (rms)
TM on	24 μrad (rms)	< 7 μrad (rms)
Cross Scan		
Systematic	±200 μrad	< ±42 μrad
Random	24 μrad (1σ)	<3 μrad
MTF (10)2 μrad bars)		
Band 1	> .36	.49-.54
Band 2	> .36	.47-.54
Band 3	> .36	.47-.52
Band 4	> .36	.45-.48

Scan Mirror Angle vs. Time Trajectory



SMP = Scan Monitor Pulse

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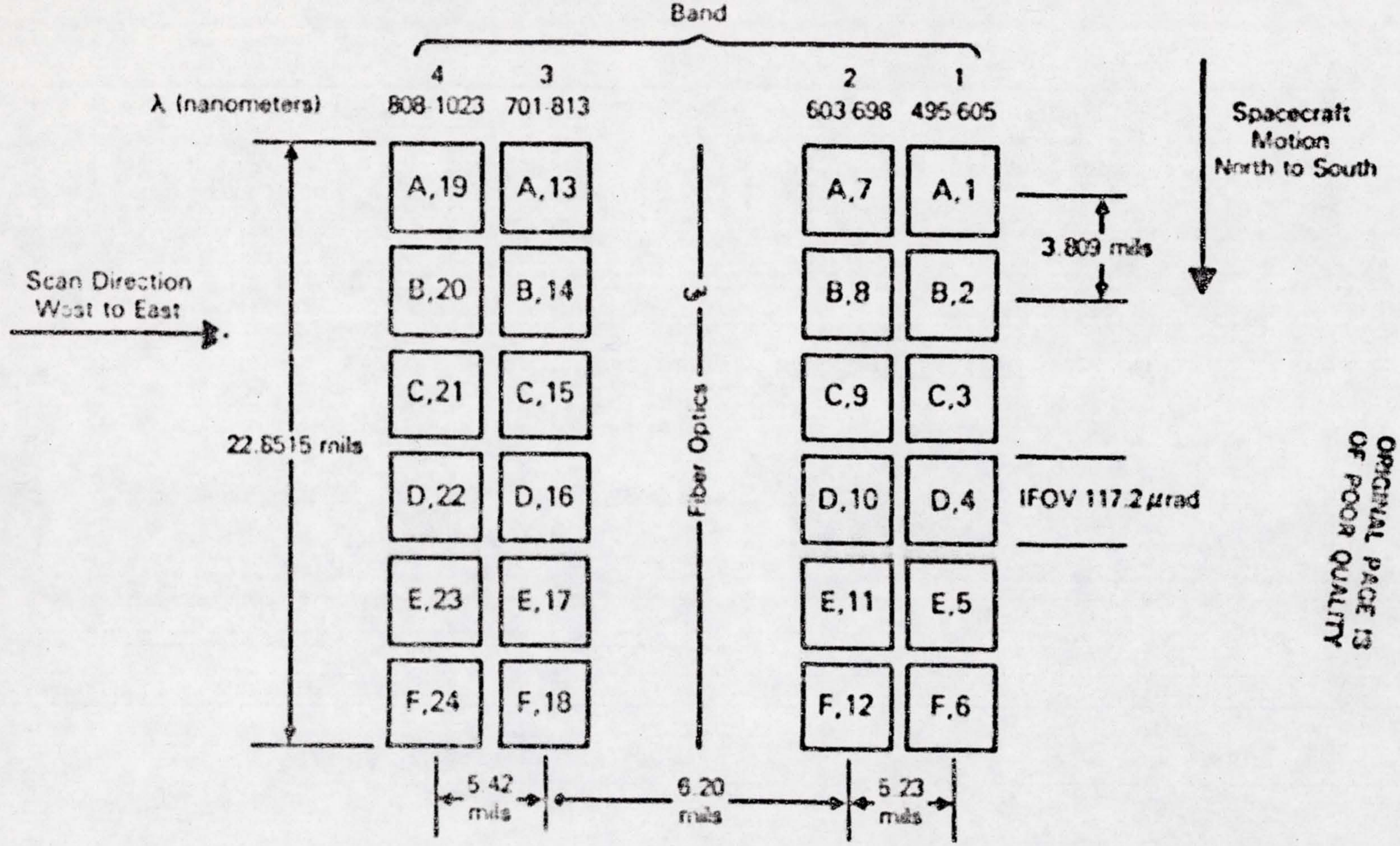
Landsat-D MSS/PF
Focal Plane Dimensions



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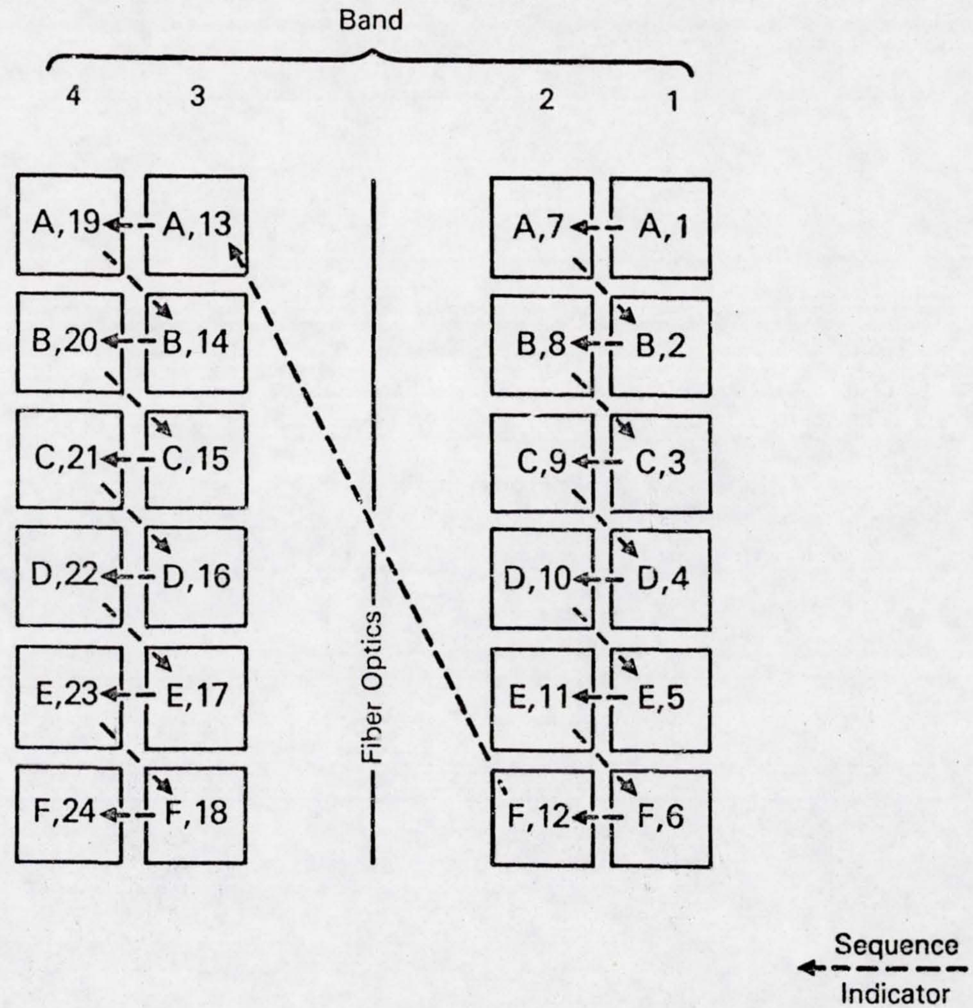
mils = 0.001 inch.

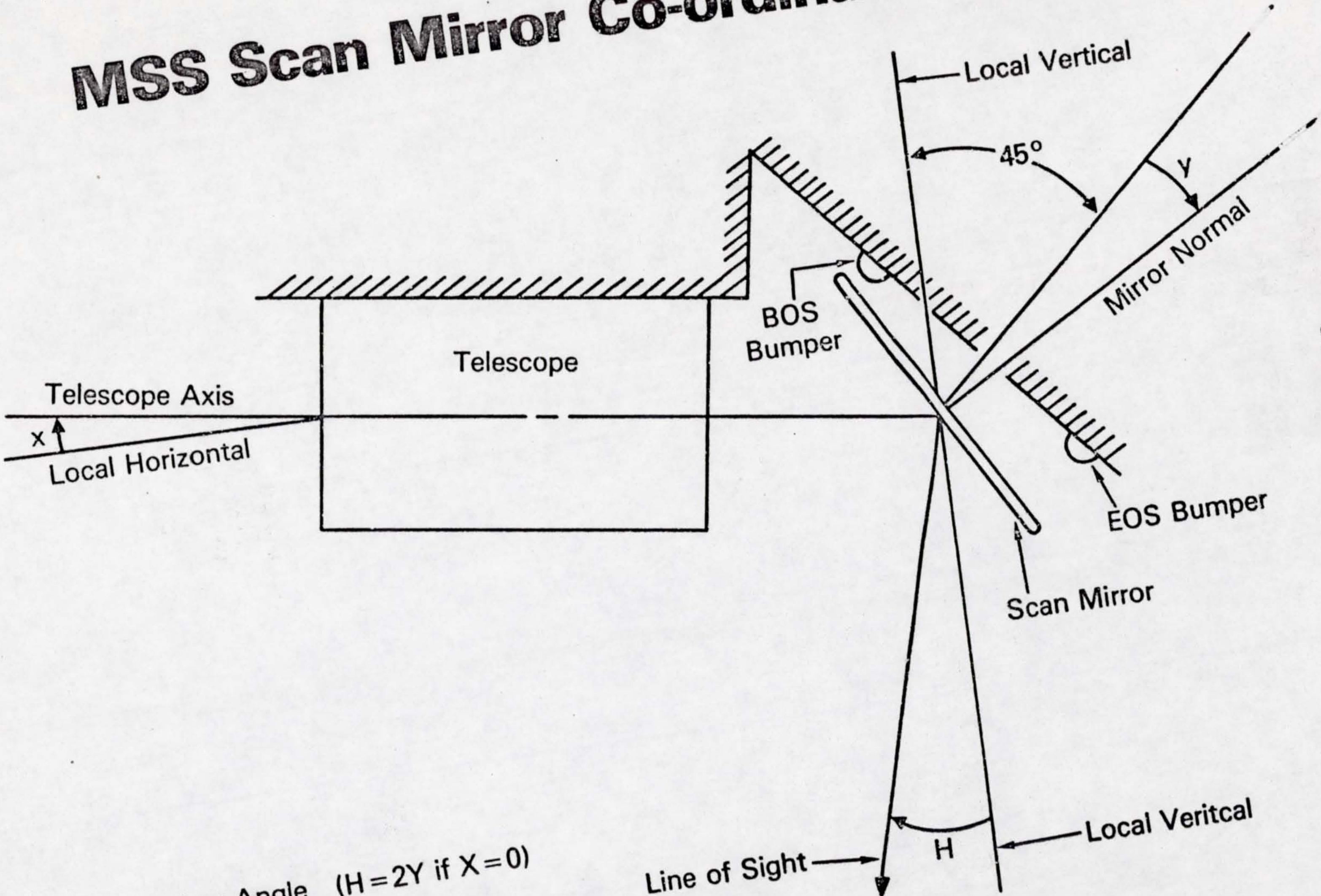
Note: Telescope Focal Length = 32.289 inches

MSS Detector Sampling Sequence



C-2

MSS Scan Mirror Co-ordinate System



H = View Angle (H = 2Y if X = 0)
Y = Mirror Angle
X = Jitter Angle

Scan Profile Equations

$$I\ddot{y} + v\dot{y} + k(y - x) = 0$$

$$y = Ae^{-Rt} \sin \omega (t + F) + B \sin (\omega_0 t -- \phi) + C \cos (\omega_0 t + \phi)$$

$$H = 2y - x$$

Where: I = Mirror Moment of Inertia

y = Mirror Angle

v = Damping Coefficient

K = Flex Pivot Spring Constant

x = Jitter Angle = $A_0 \sin (\omega_0 t + \phi)$

H = View Angle

t = Time from Beginning of Scan (BOS)

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SCAN PROFILE EQUATIONS DEFINITION

$$A = \frac{-S_0 - A_0 \sin\phi + B \sin\phi + C \cos\phi}{\sin \omega F}$$

$$R = \frac{\omega_1^{\,2}}{2\,q}$$

$$F = \frac{1}{\omega} \tan^{-1}\left[\frac{\sin \omega P}{\dfrac{x(P) - y_p(P) - S_0}{y_p(0) - x(0) - S_0}\, e^{RP} + \cos \omega P}\right]$$

1-198

$$x(P) = A_0 \sin(\omega_0 P + \phi)$$

$$x(0) = A_0 \sin\phi$$

$$y_p(P) = B \sin(\omega_0 P + \phi) + C \cos(\omega_0 P + \phi)$$

$$y_p(0) = B \sin\phi + C \cos\phi$$

$$B = \frac{A_0\left(1 - \dfrac{\omega_0^{\,2}}{\omega_1^{\,2}}\right)}{\left(1 - \dfrac{\omega_0^{\,2}}{\omega_1^{\,2}}\right)^2 + \left(\dfrac{\omega_0}{q}\right)^2}$$

$$C = \frac{-A_0\left(\dfrac{\omega_0}{q}\right)}{\left(1 - \dfrac{\omega_0^{\,2}}{\omega_1^{\,2}}\right)^2 + \left(\dfrac{\omega_0}{q}\right)^2}$$

$$\omega = \omega_1 \left[1 - \left(\frac{\omega_1}{2q}\right)^2\right]^{1/2}, \quad \omega_1 = \sqrt{\frac{k}{I}}, \quad q = \frac{k}{v}$$

Scan Profile
Zero Damping, Zero Jitter Case

$$x = v = o$$

$$y = \frac{-S_o}{\sin \frac{\omega p}{2}} \sin (t - p/2)$$

$$H = 2y$$

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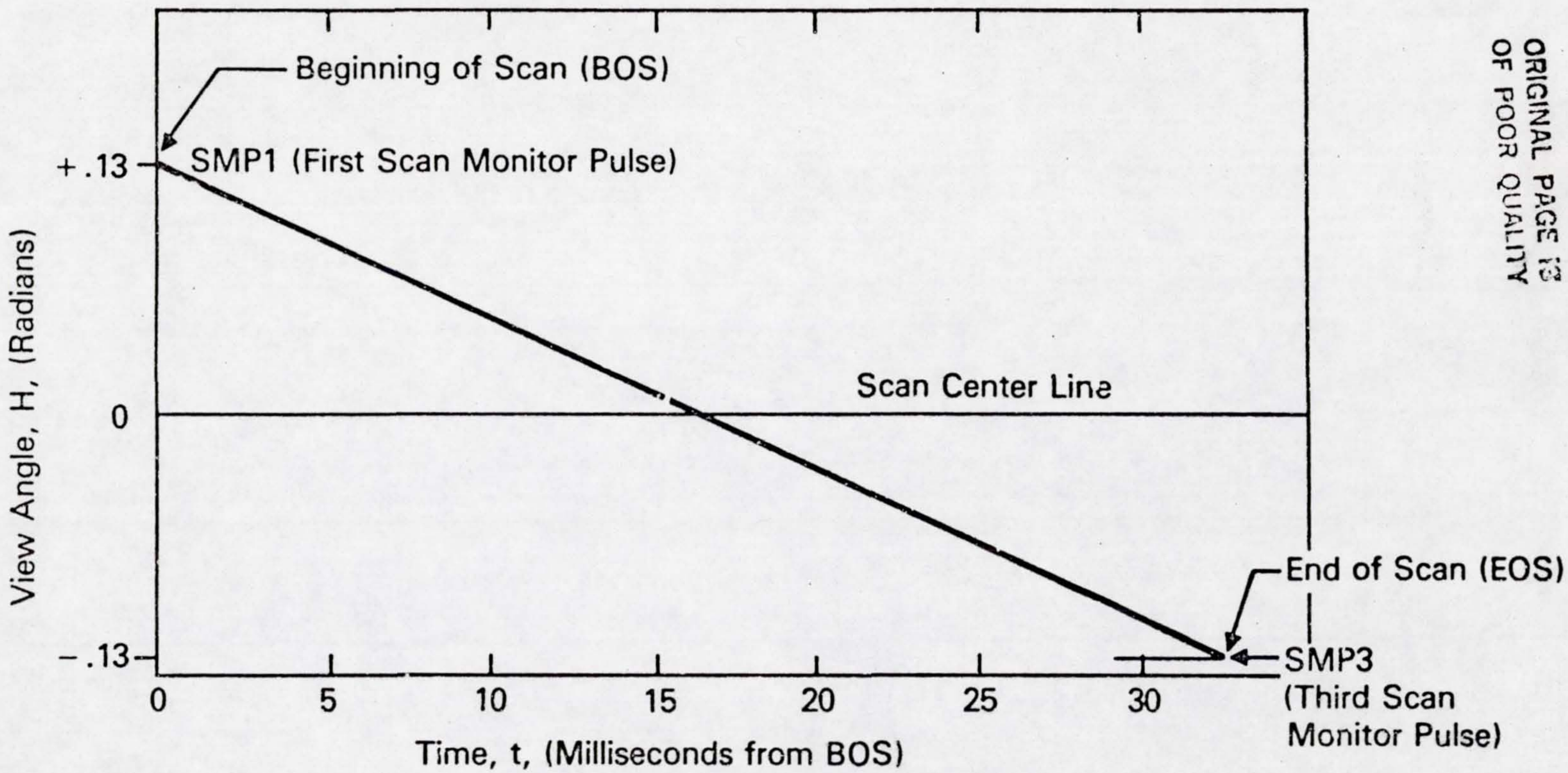
Where:

S_o = Half of Mirror Scan Angle

p = Active Scan Period

MSS Active Scan Mirror Profile



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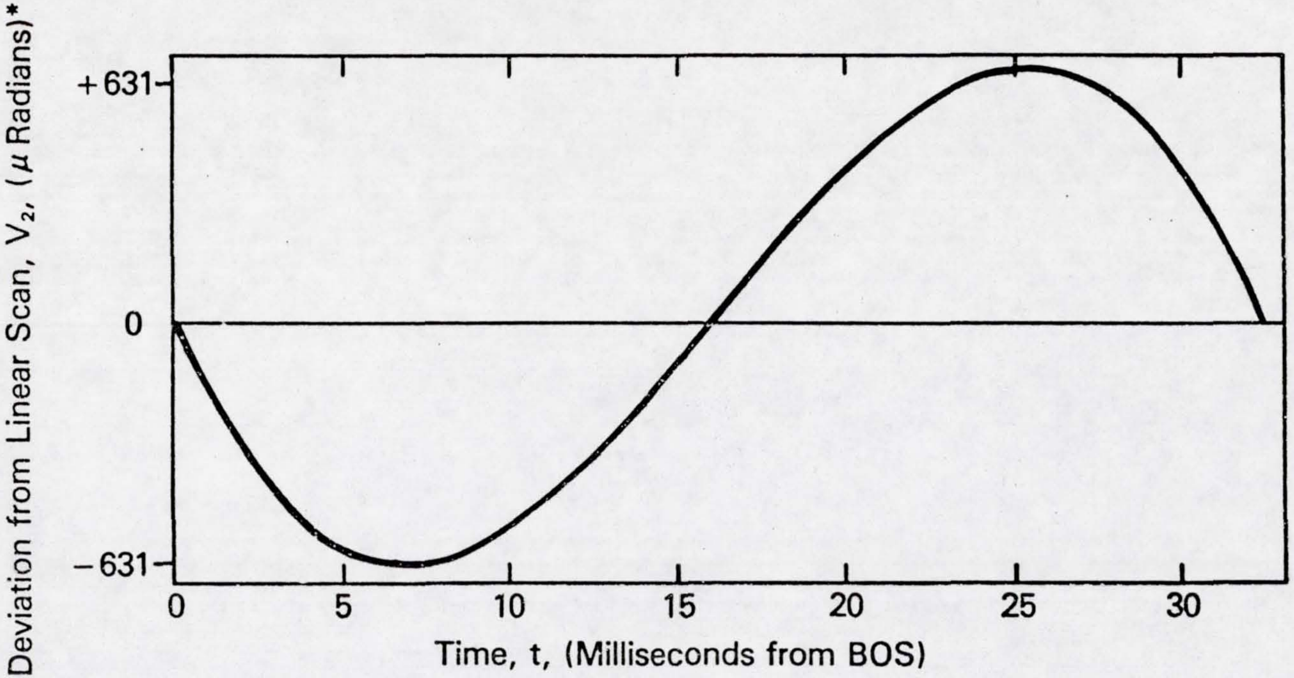
Landsat-D MSS/PF Calculated Deviation from Linear Scan

(ASSUMES NO DAMPING)



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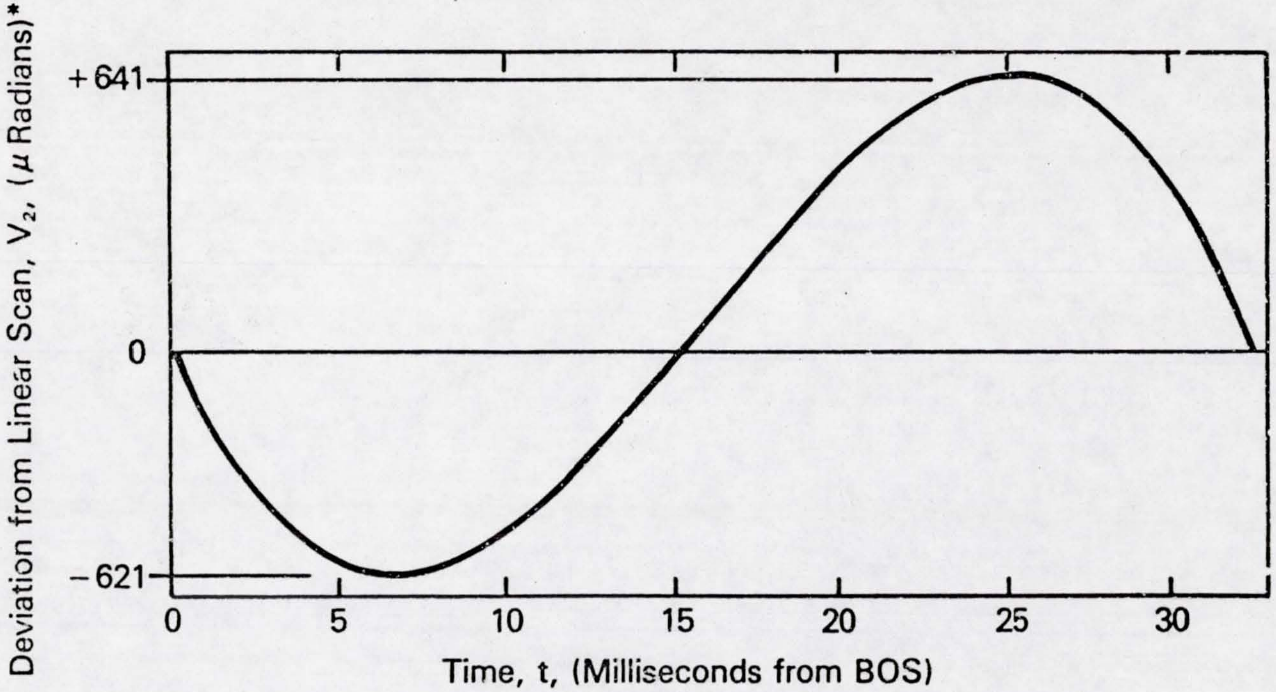
*Nominal (Linear) Scan Profile Minus Actual Profile
(Scale to be Calibrated During System Level Tests)

Landsat-D MSS/PF Deviations from Linear Scan

(ASSUMES DAMPING, BASED ON ENGINEERING MODEL MEASUREMENTS)



*Scale to be Calibrated During System Level Tests

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Protoflight MSS-D Scan Profiles
(with and without damping)

Definitions and physical values

- T - time in seconds from BOS (SMP-1)
- Y - mirror angle in radians
- H - view angle in radians
- P - active scan time (.03230 seconds)
- K - flex pivots spring constant (26.6 in lbs/rad)
- I - mirror inertia (.0923 in 16 sec^2)
- S_o - half of mirror angle from SMP-1 to SMP-3 (.065075 rad)

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Scan Profile with Damping Coeficient v = o

T(SEC)= 0	H(RAD)= .13015000	Y(RAD)= 6.5075000E-02
T(SEC)= .0008075	H(RAD)= .12379434	Y(RAD)= 6.1897171E-02
T(SEC)= .001615	H(RAD)= .11741542	Y(RAD)= 5.8707711E-02
T(SEC)= .0024225	H(RAD)= .11101444	Y(RAD)= 5.5507218E-02
T(SEC)= .00323	H(RAD)= .10459259	Y(RAD)= 5.2296296E-02
T(SEC)= .0040375	H(RAD)= 9.8151091E-02	Y(RAD)= 4.9075546E-02
T(SEC)= .004845	H(RAD)= 9.1691147E-02	Y(RAD)= 4.5845574E-02
T(SEC)= .0056525	H(RAD)= 8.5213973E-02	Y(RAD)= 4.2606987E-02
T(SEC)= .00646	H(RAD)= 7.8720786E-02	Y(RAD)= 3.9360393E-02
T(SEC)= .0072675	H(RAD)= 7.2212807E-02	Y(RAD)= 3.6106403E-02
T(SEC)= .008075	H(RAD)= 6.5691258E-02	Y(RAD)= 3.2845629E-02
T(SEC)= .0088825	H(RAD)= 5.9157364E-02	Y(RAD)= 2.9578682E-02
T(SEC)= .00969	H(RAD)= 5.2612354E-02	Y(RAD)= 2.6306177E-02
T(SEC)= .0104975	H(RAD)= 4.6057457E-02	Y(RAD)= 2.3028729E-02
T(SEC)= .011305	H(RAD)= 3.9493906E-02	Y(RAD)= 1.9746953E-02
T(SEC)= .0121125	H(RAD)= 3.2922933E-02	Y(RAD)= 1.6461466E-02
T(SEC)= .01292	H(RAD)= 2.6345773E-02	Y(RAD)= 1.3172887E-02
T(SEC)= .0137275	H(RAD)= 1.9763663E-02	Y(RAD)= 9.8818316E-03
T(SEC)= .014535	H(RAD)= 1.3177839E-02	Y(RAD)= 6.5889195E-03
T(SEC)= .0153425	H(RAD)= 6.5895386E-03	Y(RAD)= 3.2947693E-03
T(SEC)= .01615	H(RAD)=-1.5154374E-10	Y(RAD)=-7.5771868E-11
T(SEC)= .0169575	H(RAD)=-6.5895389E-03	Y(RAD)=-3.2947694E-03
T(SEC)= .017765	H(RAD)=-1.3177839E-02	Y(RAD)=-6.5889196E-03
T(SEC)= .0185725	H(RAD)=-1.9763663E-02	Y(RAD)=-9.8818317E-03
T(SEC)= .01938	H(RAD)=-2.6345774E-02	Y(RAD)=-1.3172887E-02

T(SEC)= .0201875	H(RAD)=-3.2922933E-02	Y(RAD)=-1.6461467E-02
T(SEC)= .020995	H(RAD)=-3.9493906E-02	Y(RAD)=-1.9746953E-02
T(SEC)= .0218025	H(RAD)=-4.6057458E-02	Y(RAD)=-2.3028729E-02
T(SEC)= .02261	H(RAD)=-5.2612354E-02	Y(RAD)=-2.6306177E-02
T(SEC)= .0234175	H(RAD)=-5.9157364E-02	Y(RAD)=-2.9578682E-02
T(SEC)= .024225	H(RAD)=-6.5691258E-02	Y(RAD)=-3.2845629E-02
T(SEC)= .0250325	H(RAD)=-7.2212807E-02	Y(RAD)=-3.6106404E-02
T(SEC)= .02584	H(RAD)=-7.8720787E-02	Y(RAD)=-3.9360393E-02
T(SEC)= .0266475	H(RAD)=-8.5213973E-02	Y(RAD)=-4.2606987E-02
T(SEC)= .027455	H(RAD)=-9.1691147E-02	Y(RAD)=-4.5845574E-02
T(SEC)= .0282625	H(RAD)=-9.8151091E-02	Y(RAD)=-4.9075546E-02
T(SEC)= .02907	H(RAD)=-.10459259	Y(RAD)=-5.2296296E-02
T(SEC)= .0298775	H(RAD)=-.11101444	Y(RAD)=-5.5507218E-02
T(SEC)= .030685	H(RAD)=-.11741542	Y(RAD)=-5.8707711E-02
T(SEC)= .0314925	H(RAD)=-.12379434	Y(RAD)=-6.1897171E-02
T(SEC)= .0323	H(RAD)=-.13015000	Y(RAD)=-6.5075000E-02

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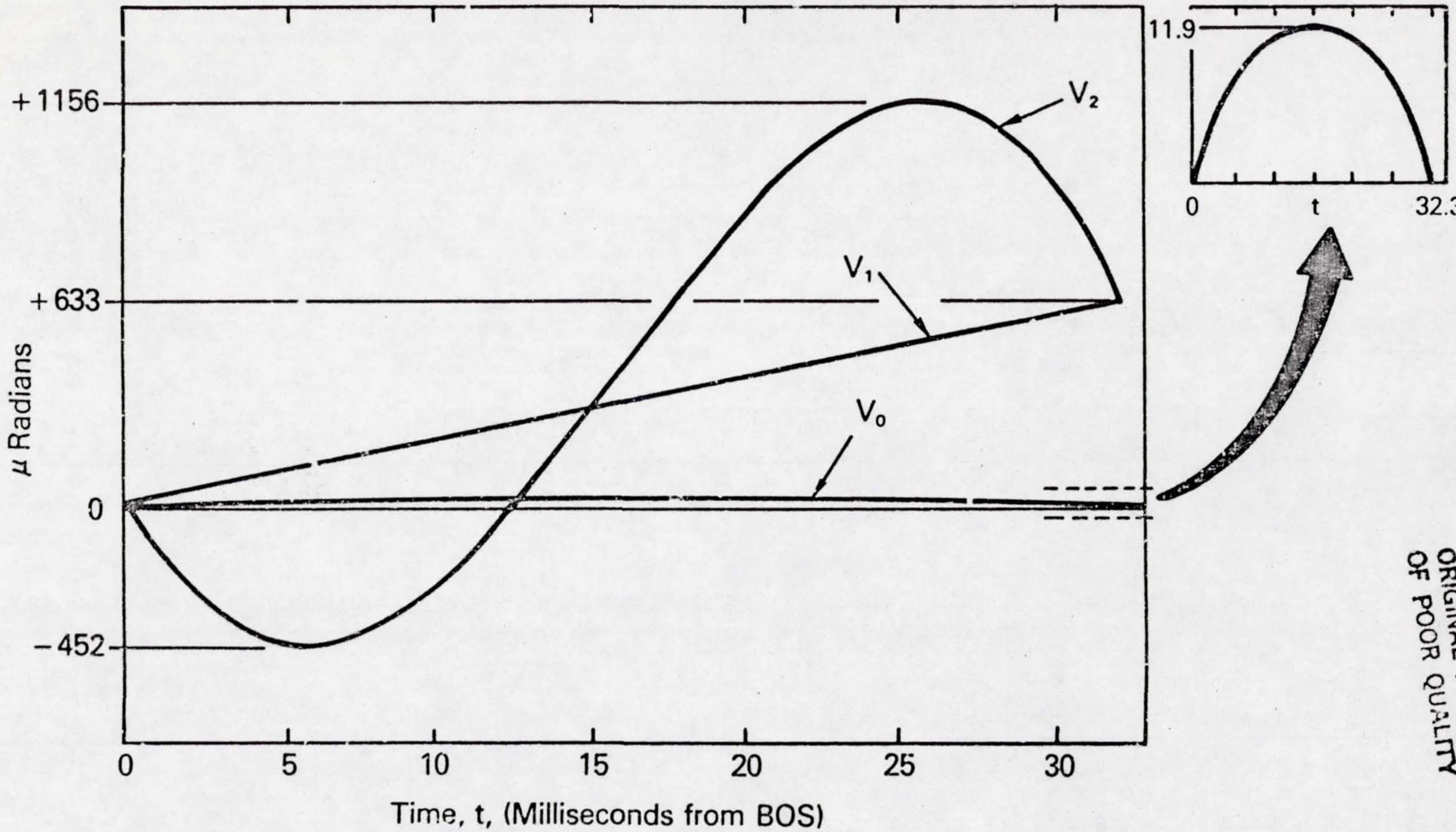
Scan Profile with Damping Coeficient $v = 107 \times 10^{-6}$ ft. - 16 - sec/rad

T(SEC)= 0	H(RAD)= .13015000	Y(RAD)= 6.5075000E-02
T(SEC)= .0008075	H(RAD)= .12379288	Y(RAD)= 6.1896439E-02
T(SEC)= .001615	H(RAD)= .11741256	Y(RAD)= 5.8706282E-02
T(SEC)= .0024225	H(RAD)= .11101026	Y(RAD)= 5.5505130E-02
T(SEC)= .00323	H(RAD)= .10458717	Y(RAD)= 5.2293583E-02
T(SEC)= .0040375	H(RAD)= 9.8144493E-02	Y(RAD)= 4.9072246E-02
T(SEC)= .004845	H(RAD)= 9.1683448E-02	Y(RAD)= 4.5841724E-02
T(SEC)= .0056525	H(RAD)= 8.5205248E-02	Y(RAD)= 4.2602624E-02
T(SEC)= .00646	H(RAD)= 7.8711110E-02	Y(RAD)= 3.9355555E-02
T(SEC)= .0072675	H(RAD)= 7.2202253E-02	Y(RAD)= 3.6101127E-02
T(SEC)= .008075	H(RAD)= 6.5679902E-02	Y(RAD)= 3.2839951E-02
T(SEC)= .0088825	H(RAD)= 5.9145282E-02	Y(RAD)= 2.9572641E-02
T(SEC)= .00969	H(RAD)= 5.2599622E-02	Y(RAD)= 2.6299811E-02
T(SEC)= .0104975	H(RAD)= 4.6044150E-02	Y(RAD)= 2.3022075E-02
T(SEC)= .011305	H(RAD)= 3.9480101E-02	Y(RAD)= 1.9740050E-02
T(SEC)= .0121125	H(RAD)= 3.2908706E-02	Y(RAD)= 1.6454353E-02
T(SEC)= .01292	H(RAD)= 2.6331201E-02	Y(RAD)= 1.3165600E-02
T(SEC)= .0137275	H(RAD)= 1.9748822E-02	Y(RAD)= 9.8744108E-03
T(SEC)= .014535	H(RAD)= 1.3162805E-02	Y(RAD)= 6.5814027E-03
T(SEC)= .0153425	H(RAD)= 6.5743898E-03	Y(RAD)= 3.2871949E-03
T(SEC)= .01615	H(RAD)=-1.5187312E-05	Y(RAD)=-7.5936560E-06
T(SEC)= .0169575	H(RAD)=-6.6046875E-03	Y(RAD)=-3.3023438E-03
T(SEC)= .017765	H(RAD)=-1.3192873E-02	Y(RAD)=-6.5964363E-03
T(SEC)= .0185725	H(RAD)=-1.9778505E-02	Y(RAD)=-9.8892523E-03
T(SEC)= .01938	H(RAD)=-2.6360346E-02	Y(RAD)=-1.3180173E-02
T(SEC)= .0201875	H(RAD)=-3.2937160E-02	Y(RAD)=-1.6468580E-02

T(SEC)= .020995	H(RAD)=-3.9507711E-02	Y(RAD)=-1.9753855E-02
T(SEC)= .0218025	H(RAD)=-4.6070764E-02	Y(RAD)=-2.3035382E-02
T(SEC)= .02261	H(RAD)=-5.2625086E-02	Y(RAD)=-2.6312543E-02
T(SEC)= .0234175	H(RAD)=-5.9169445E-02	Y(RAD)=-2.9584723E-02
T(SEC)= .024225	H(RAD)=-6.5702617E-02	Y(RAD)=-3.2851306E-02
T(SEC)= .0250325	H(RAD)=-7.2223360E-02	Y(RAD)=-3.6111680E-02
T(SEC)= .02584	H(RAD)=-7.8730463E-02	Y(RAD)=-3.9365231E-02
T(SEC)= .0266475	H(RAD)=-8.5222698E-02	Y(RAD)=-4.2611349E-02
T(SEC)= .027455	H(RAD)=-9.1698845E-02	Y(RAD)=-4.5849423E-02
T(SEC)= .0282625	H(RAD)=-9.8157689E-02	Y(RAD)=-4.9078845E-02
T(SEC)= .02907	H(RAD)=-.10459802	Y(RAD)=-5.2299008E-02
T(SEC)= .0298775	H(RAD)=-.11101861	Y(RAD)=-5.5509307E-02
T(SEC)= .030685	H(RAD)=-.11741928	Y(RAD)=-5.8709139E-02
T(SEC)= .0314925	H(RAD)=-.12379581	Y(RAD)=-6.1897903E-02
T(SEC)= .0323	H(RAD)=-.13015000	Y(RAD)=-6.5075000E-02

Line Length Variation Effects on Scan Mirror Profile



Line Length Error = −78 μsec.
V_0 = Error Remaining after "Rubberband" Correction
V_1 – Error Resulting from Shortened Line Length if Baseline Profile is Used
V_2 – Deviation from Linear Scan

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MSS Geometric Processing and Calibration

Joan Brooks

GEOMETRIC CORRECTION AGENDA

- REQUIREMENTS
- OVERVIEW OF CORRECTION DATA GENERATION
- SYSTEMATIC CORRECTION DATA GENERATION
- GEODETIC CORRECTION DATA GENERATION
- GEOMETRIC CORRECTION CALIBRATION

SUMMARY OF KEY GEOMETRIC CORRECTION REQUIREMENTS

- COMPLETE GEOMETRIC CORRECTION CALCULATION
  - EXCEPT NO TERRAIN RELIEF COMPENSATION
- USE EPHEMERIS FROM GPS OR ORBIT SUPPORT COMPUTING DIVISION (2 DAY PREDICT)
- MAP PROJECTIONS
  - UNIVERSAL TRANSVERSE MERCATOR/POLAR STEREOGRAPHIC
  - SPACE OBLIQUE MERCATOR
- INTERACTIVE CONTROL POINT LIBRARY BUILD
  - SELECT CONTROL POINTS FROM MAPS AND PHOTOGRAPHIC IMAGERY
  - 100 CONTROL POINTS/DAY
  - CAPABILITY TO USE THE EXISTING LANDSAT 2/3 LIBRARY
  - ELEVATION OF CONTROL POINTS MUST BE USED
- SCENE FRAMING BASED UPON A WORLD REFERENCE SYSTEM (WRS)
- FULLY CORRECTED MSS IMAGERY
  - FOR SENSOR AND PROCESS QUALITY ASSESSMENT
  - RESAMPLING USING NEAREST NEIGHBOR OR CUBIC CONVOLUTION
  - CCT AND 241 MM FILM OUTPUTS
- MSS ARCHIVAL HIGH DENSITY TAPE
  - FORMAT AND CONTENT MUST CONFORM WITH IPF-ICD-201
  - DEFINES MSS GEOMETRIC CORRECTION DATA

SUMMARY OF KEY GEOMETRIC CORRECTION REQUIREMENTS (ACCURACY)

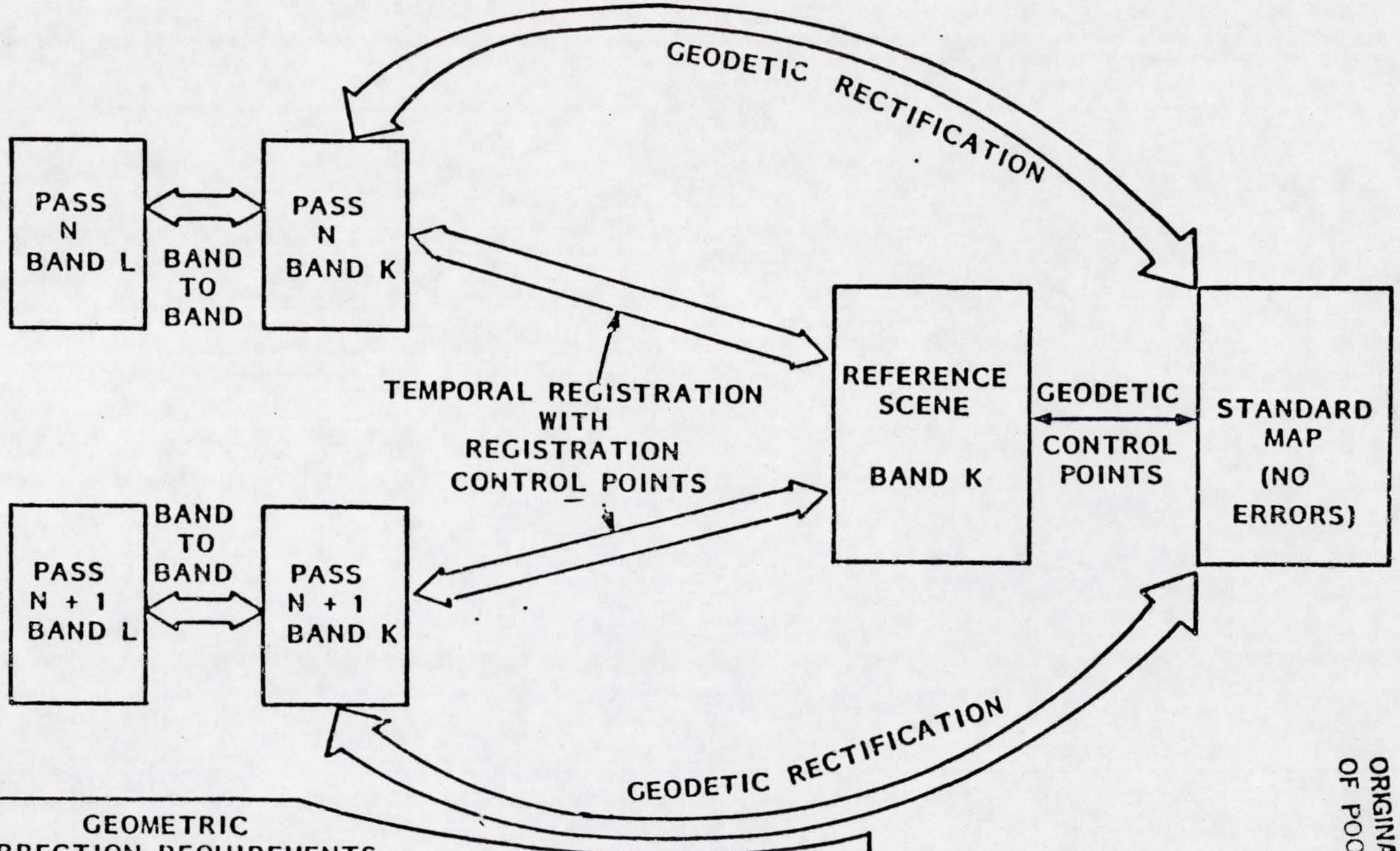
GEODETIC RECTIFICATION

- 0.5 PIXEL (90% OF THE TIME)
- REFERENCE TO STANDARD MAP
- ASSUME ACCURATE GROUND CONTROL POINTS
- VERIFIED OVER AREAS WITH NO TOPOGRAPHICAL VARIATIONS

TEMPORAL REGISTRATION

- 0.3 PIXEL (90% OF THE TIME)
- ADEQUATE INSTRUMENT PERFORMANCE

GEOMETRIC ACCURACY SPECIFICATIONS



GEOMETRIC CORRECTION REQUIREMENTS
90% OF THE TIME

GEODETIC 0.5 PIXEL
TEMPORAL 0.3 PIXEL (REGISTRANT TO REFERENCE)

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TEMPORAL REGISTRATION REQUIREMENT INTERPRETATION

- TEMPORAL REGISTRATION REQUIREMENT: 0.3 PIXEL, 90% OF THE TIME
- CLARIFICATIONS
  - SPECIFICATION APPLIES PER AXIS OF THE OUTPUT SCENE (X, Y)
  - PIXEL DEFINED AS INPUT PIXEL SIZE

    42.5 μRADIAN FOR TM

    117.2 μRADIAN FOR MSS

    (AVOIDS ALTITUDE EFFECTS AND RESTRAINT OF REDUCED TM OUTPUT PIXEL SIZE, 28.5 METER)
  - ADEQUATE NUMBER AND DISTRIBUTION OF CONTROL POINTS
  - ELEVATION OF CONTROL POINTS MUST BE KNOWN
  - VERIFIED OVER AREAS WITH NEGLIGIBLE EARTH TOPOLOGICAL VARIATIONS

TEMPORAL REGISTRATION VERIFICATION

- CATAGEORIES OF ERRORS

  - BIASES: "FIXED" OFFSET BETWEEN REFERENCE AND SUBSEQUENT PASS. RESULTS PRIMARILY FROM ATTITUDE, ALIGNMENT AND EPHEMERIS UNCERTAINTY. RANDOM OVER THE ENSEMBLE OF ESTIMATION EVENTS. ENSEMBLE VARIANCE σ_B^2.

  - RANDOM: INTERNAL ERRORS WITHIN ONE SCENE. RESULTS FROM SCAN MIRROR NON-REPEATABILITY, RESIDUAL JITTER, PROCESSING LINEARIZATION AND COMPUTATIONAL LIMITATIONS. ONE SCENE VARIANCE σ_R^2.

  - MEASUREMENT: ERROR IN CORRELATING TWO CONTROL POINTS. VARIANCE σ_M^2.

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MULTISPECTRAL SCANNER TEMPORAL REGISTRATION ERROR IN PIXEL (117.2 μr) 90% OF THE TIME

ERROR SOURCE	MSS-D PERFORMING AT SPEC LEVEL				MSS-D PERFORMING AT MSS-3 LEVEL			
	CROSS TRACK		ALONG TRACK		CROSS TRACK		ALONG TRACK	
	BIAS	RANDOM	BIAS	RANDOM	BIAS	RANDOM	BIAS	RANDOM
MULTISPECTRAL SCANNER								
SCAN REPEATABILITY	-	$.337\sqrt{2}$	-	$.463\sqrt{2}$	-	$.112\sqrt{2}$	-	$.049\sqrt{2}$
BAND-TO-BAND	-	-	-	-	-	-	-	-
SCAN UNDERLAP/OVERLAP								
WORST CASE 45°N	-	-	-	$.059\sqrt{2}$	-	-	-	$.059\sqrt{2}$
81.8°S	-	-	-	$.126\sqrt{2}$	-	-	-	$.126\sqrt{2}$
SPACECRAFT								
JITTER	-	$.102\sqrt{2}$	-	$.102\sqrt{2}$	-	$.102\sqrt{2}$	-	$.102\sqrt{2}$
GROUND PROCESSING								
• ATTITUDE/EPHEMERIS RESIDUAL	.269	-	.318	-	.165	-	.165	-
• SYSTEMATIC CORRECTION DATA GENERATION	-	$.030\sqrt{2}$	-	$.030\sqrt{2}$	-	$.030\sqrt{2}$		$.030\sqrt{2}$
• GEODETIC CORRECTION DATA GENERATION	-	$.030\sqrt{2}$	-	$.030\sqrt{2}$	-	$.030\sqrt{2}$	-	$.030\sqrt{2}$
• CORRECTION DATA INTER-POLATION	-	$.030\sqrt{2}$	-	$.030\sqrt{2}$	-	$.030\sqrt{2}$	-	$.030\sqrt{2}$
• RESAMPLING	-	$.014\sqrt{2}$	-	$.014\sqrt{2}$	-	$.014\sqrt{2}$	-	$.014\sqrt{2}$
RSS SUBTOTAL	.269	.505	.318	.699	.165	.230	.165	.254 (81.8°S) .199 (45°N)
RANDOM + BIAS RSS	.572		.768 (81.8°S)		.283		.303 (81.8°S) .259 (45°N)	
SYSTEM SPECIFICATION	.3		.3		.3		.3	

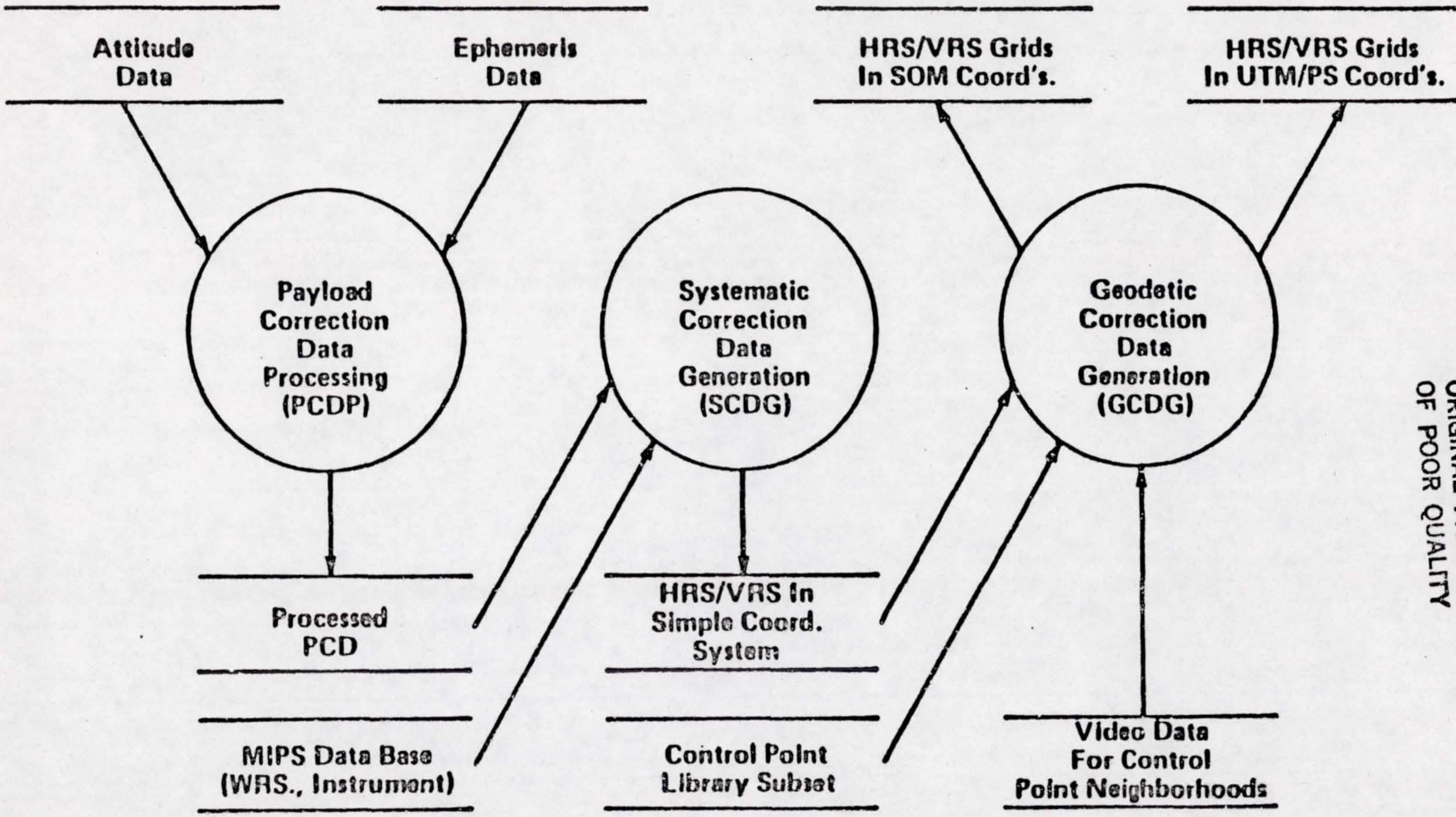
OVERVIEW OF CORRECTION DATA GENERATION

- SYSTEMATIC CORRECTION DATA - THREE STAGES
  - OFFLINE DEVELOPMENT OF NOMINAL CORRECTION DATA
  - ONLINE ATTITUDE/EPHEMERIS PROCESSING, SCENE CENTER DETERMINATION
  - ONLINE UPDATE OF NOMINAL CORRECTION DATA USING PROCESSED ATTITUDE/EPHEMERIS
- GEODETIC CORRECTION DATA - ONLINE
  - EXTRACTION AND CORRECTION OF CONTROL POINT NEIGHBORHOODS USING SYSTEMATIC CORRECTION DATA
  - CORRELATION OF CONTROL POINT LIBRARY CHIPS TO CONTROL POINT NEIGHBORHOODS
  - FILTERING OF CONTROL POINT DISLOCATION TO DETERMINE EPHEMERIS/ATTITUDE CORRECTIONS
  - UPDATE OF SYSTEMATIC CORRECTION DATA USING FILTER OUTPUTS

OVERVIEW OF GEOMETRIC CORRECTION (CONTINUED)

- REFORMATTING OF CORRECTION DATA TO HORIZONTAL AND VERTICAL RESAMPLING MATRICES (HRS/VRS)

Overview of MSS Geometric Correction
Data Generation for a Scene



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Legend

HRS: Horizontal Resampling
VRS: Vertical Resampling
SOM: Space Oblique Mercator
UTM: Universal Transverse Mercator
PS: Polar Stereographic

Systematic Correction Of Imagery: Effects Modeled

- Spacecraft Ephemeris (Input)
- Spacecraft Attitude (Input)
- Scanner Misalignment (Parameters)
- Scan Angle Profile (Parameterized Model)
- Earth Geoid (Parameterized Model)
- Earth Rotation (Parameterized Model)
- World Reference System Scene Centers
- Calculations Performed for Single Detector in Center of Detector Array –
  - Band-Line Adjustments (BLA) Applied Separately
  - Line Length Corrections Applied Separately

MSS Mirror Model for SCDG

- $\rho(i) = 2 \cdot e^{-\beta(t-t_0)} \{A \sin \omega (t_0 + [i-1] \Delta t)\}$

  ρ = Scan Angle

  i = Pixel Number

  Δt = Sampling Time

  t_0 = Line Start Time

  ω = Mirror Frequency

  A = Amplitude

  β = DAMPING CONSTANT

- Along Scan Only (Roll Axis)
- Need Shape for Cross Scan (Pitch/Yaw vs i)

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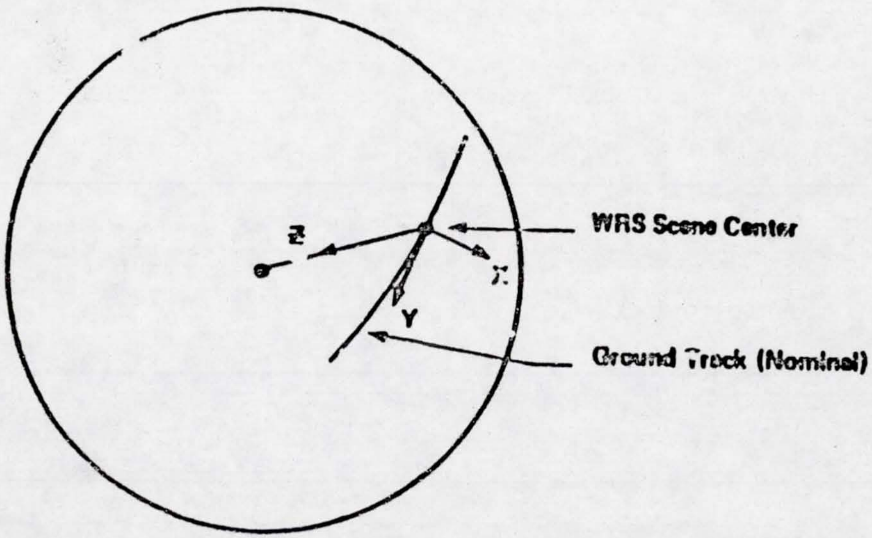
Coordinate System For Basic Calculations

Standard Coordinate System:

- **Origin at WRS Scene Center**
- **X-Axis Along S/C Nominal Angular Momentum Vector**
- **Z-Axis Earth Center Pointing**
- **Y-Axis Completes Right Hand Coordinate System (Parallel to SC Nominal Inertial Velocity)**



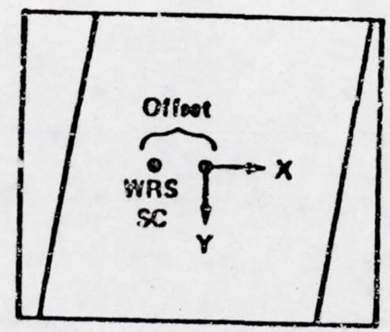


Image Centered In Frame

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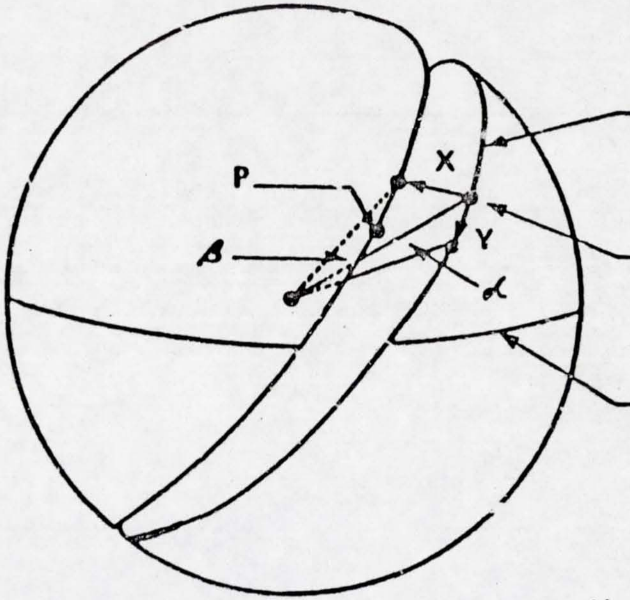
Oblique Mercator Coordinates For The Sphere



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$$X = \frac{R_e}{2} \; LN \left(\frac{1 + SIN \, \beta}{1 - SIN \, \beta} \right)$$

$$Y = R_e \cdot \alpha$$

α = Oblique Longitude of P

β = Oblique Latitude of P

Re = Local Earth Radius
at WRS Scene Cent

- Highly Conformal Within a Scene
- Good Local Approximation to Space Oblique Mercator

Systematic Correction Functions (SCF)

Objective: Associate (X, Y) in Processed Image with (i, j) in Raw Video

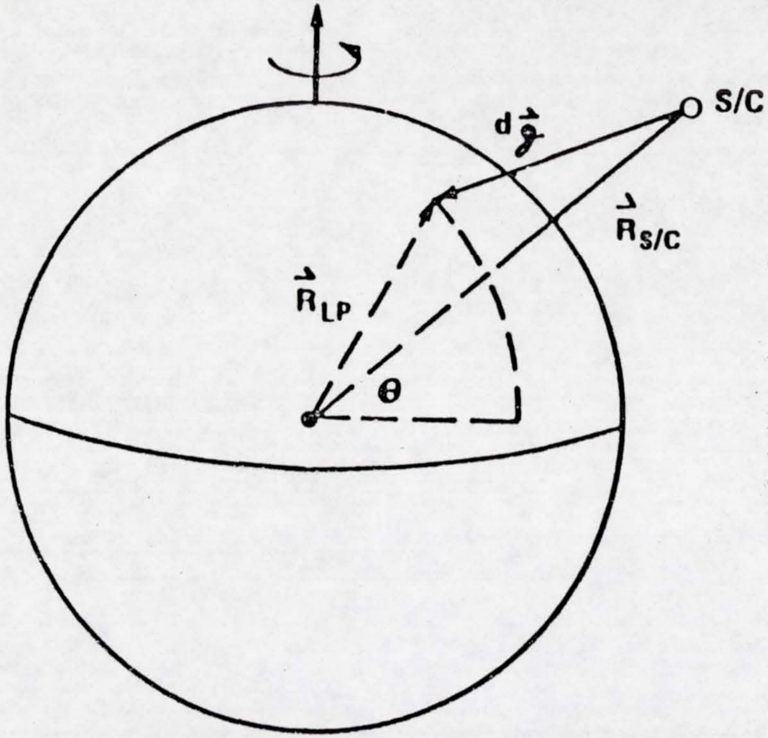
i = Pixel Number (Sample Time)

j = Line Number (Scan Time)

(i,j) Defines Unique Time t Relative to Scene Center Time

$$\text{Result: }\left.\begin{aligned} X &= f(i,j) \\ Y &= g(i,j) \end{aligned}\right\} \text{ For Given Ephemeris and Attitude}$$

Systematic Corrections Functions: The Lookpoint Calculation



Ellipsoidal Earth

- In ECI Coordinates, solved for $\underline{\underline{(\theta, \lambda')}}$

$$\vec{R}_{LP}(\theta, \lambda') = \vec{R}_{s/c}(t) + d\vec{g}(t)$$

t From Pixel Number i

Scan Line j

Scene Center Time

$\vec{R}_{S/C}(t)$ From Ephemeris

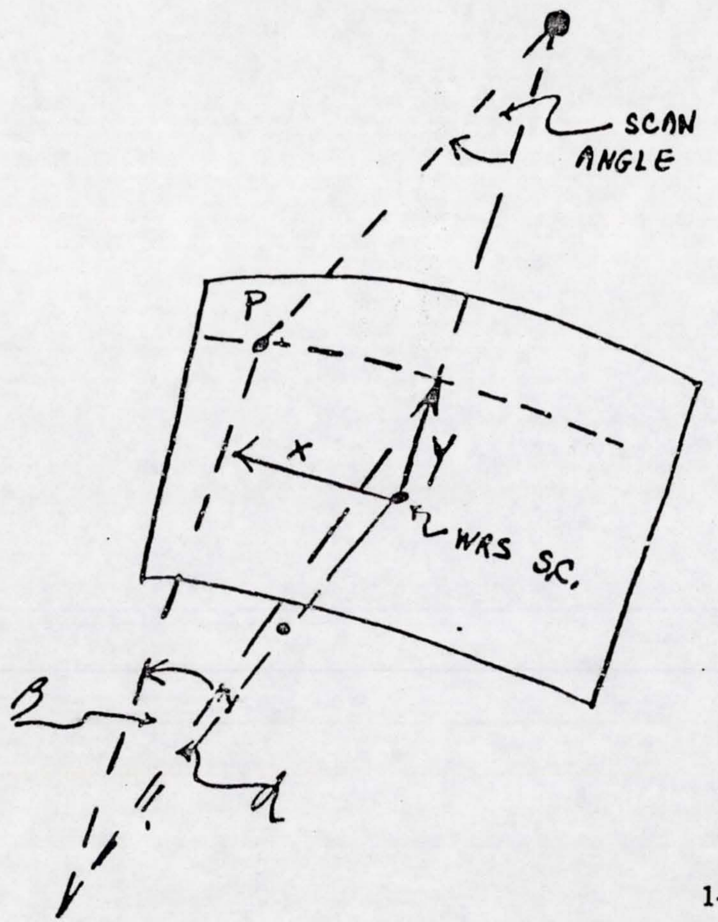
$\vec{g}(t)$ From Scan Profile, Alignment, Attitude Data

- Transform to ECEF Coordinates

  $\lambda(i, j)$ From λ', Earth Spin
- Transform (θ, λ) to (α, β)
- Transform (α, β) to (x, y)

Nominal Systematic Correction Functions (SCF_0)

- Spacecraft in Orbit that Determines WRS Scene Centers (Nominal Orbit)
- Spacecraft and Sensor have Nominal Pointing (~~[illegible]~~ Nominal Attitude Data)



$$\left.\begin{aligned} x_0 &= f_0(i, j) \\ y_0 &= g_0(i, j) \end{aligned}\right\} SCF_0$$

Xo, Yo Independent of Spacecraft Ephemeris and Attitude

Properties Of Systematic Correction Functions

- Highly Linear in Spacecraft Parameter Biases

$$x(i,j,\vec{\delta}) = x_0(i,j) + \sum_{\ell} \frac{\partial x(i,j)}{\partial \delta_\ell} \delta_\ell(i,j)$$

$$y(i,j,\vec{\delta}) = y_0(i,j) + \sum_{\ell} \frac{\partial y(i,j)}{\partial \delta_\ell} \delta_\ell(i,j)$$

- Analytic Expressions for Partial Derivatives Defined Over Entire Grid

- Spacecraft Parameter Biases

$\delta\alpha$ – Bias in Oblique Longitude
$\delta\beta$ – Bias in Oblique Latitude
δh – Bias in S/C Radial Location
$\delta\theta_p$ – Pitch Angle
$\delta\theta_r$ – Roll Angle
$\delta\theta_y$ – Yaw Angle

- Biases Generally Functions of Time

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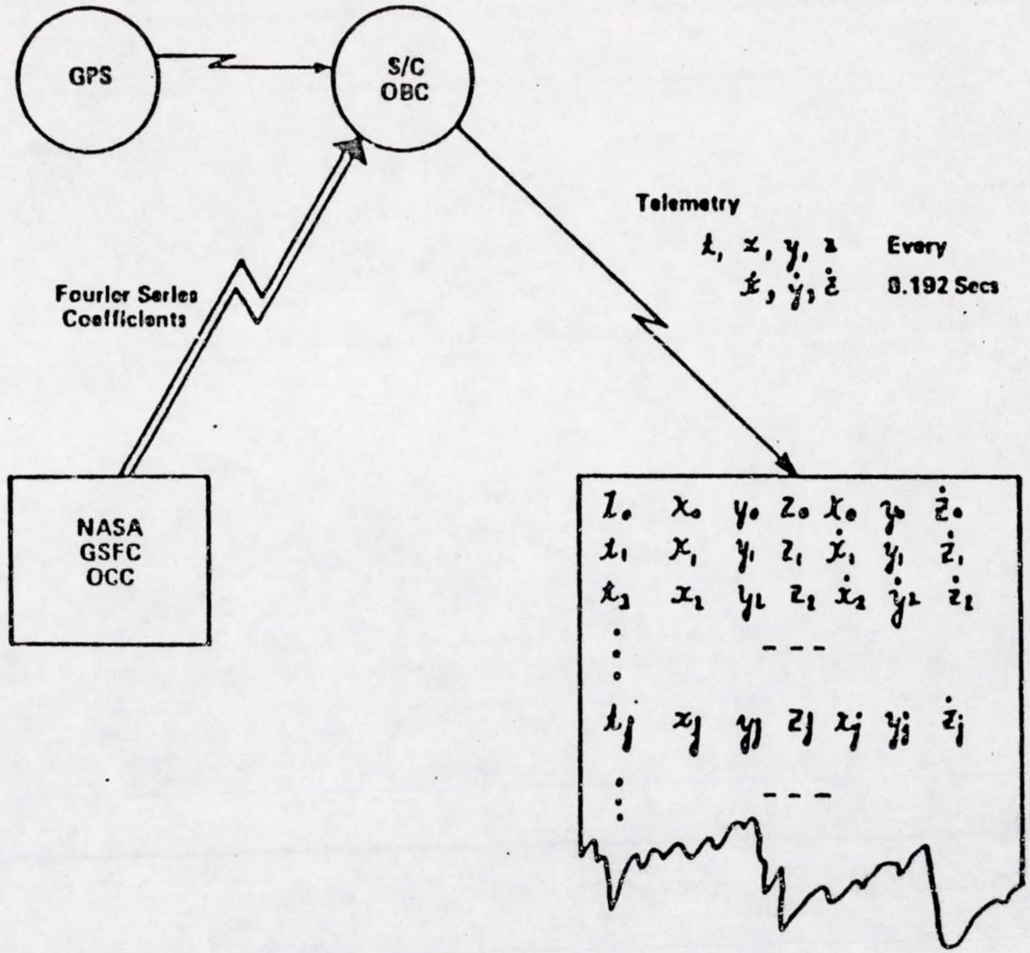
Offline Generation of Nominal Systematic Correction Functions/Partial Derivatives

- SCF_O Generated on Grid 41 (Along Scan) x 11 (Along Track)
- Partial Derivatives (PD) Generated on Grid 5 (Along Scan) x 3 (Along Track)
- Linear Interpolation Suffices
- Functions of WRS Scene Center <u>Latitude</u> Only
- Stored for Single Reference Path, Along with Nominal Ephemeris and WRS Scene Center Data
- Total Data Base $<$1.5 MBytes

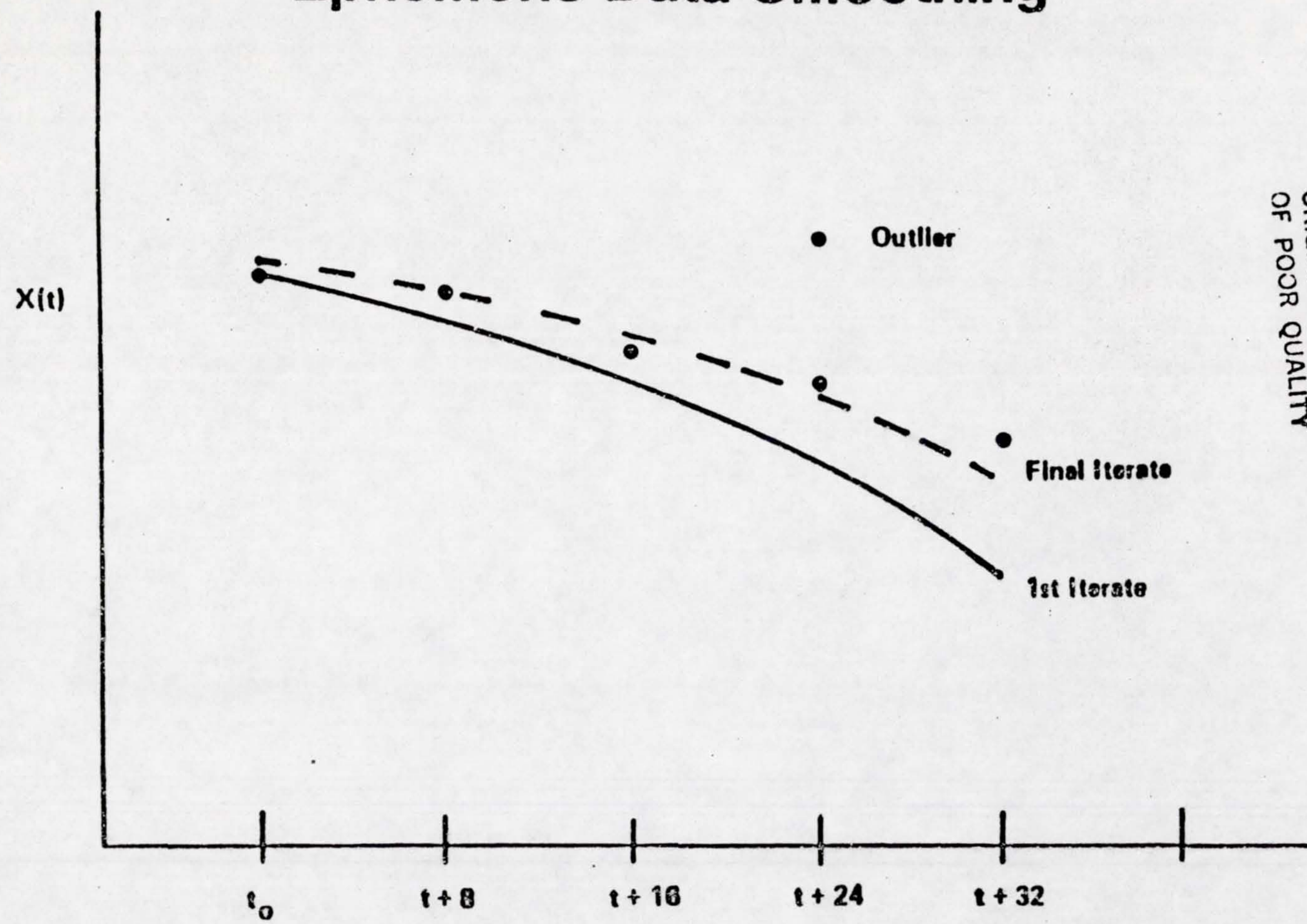
Ephemeris Processing

- Received Ephemeris has been Processed on the OBC
- May Be Contaminated By
  - Noise
  - Outliers (Transmission Errors)
  - Bias (Ground Truth Required for Removal)
- Smoothing to Remove Noise (J2 Model with Drag)
- Outlier Detection/Removal (Tast on Angular Momentum)
- Bad Data Point Count/Residuals for Quality
- Mean Residual Error (Exclusive of Bias) – approximately 10M

Source of Ephemeris



Ephemeris Data Smoothing



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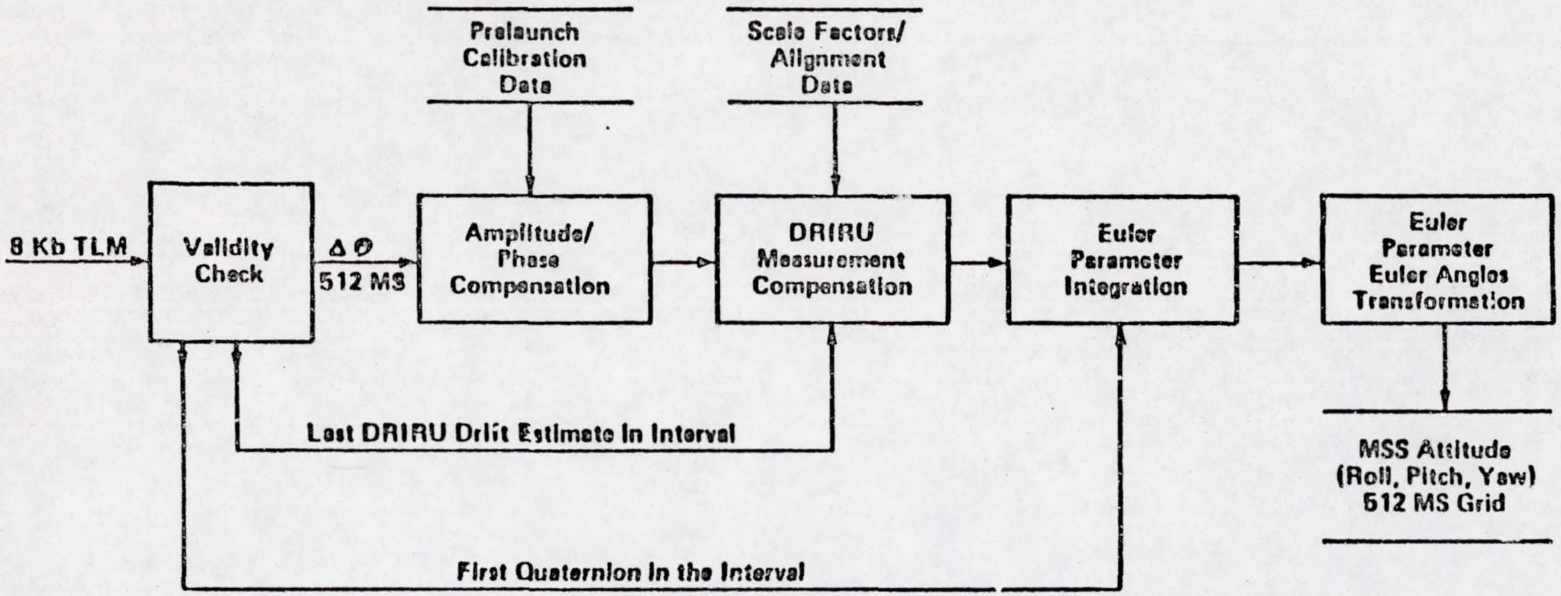
- Outlier rejection criterion: angular momentum error > 0.002 x angular momentum

Attitude Data Processing

- Received from the Spacecraft
  - Quaternions on a 4.096 Second Grid
  - Angular Increments (Pitch, Roll, Yaw) on a 0.512 Second Grid, Filtered (Frequencies less than 0.5 Hz)
  - Data in Earth Centered InertialCoordinate System

- Required Processing
  - Phase and Amplitude Compensation for Angular Increments
  - Limit Checking to Remove Outliers (Transmission Error)
  - Integration of Euler Parameters (Rates from Angular Increments)
  - Quality Checks

Data Flow in MSS Attitude Data Processing

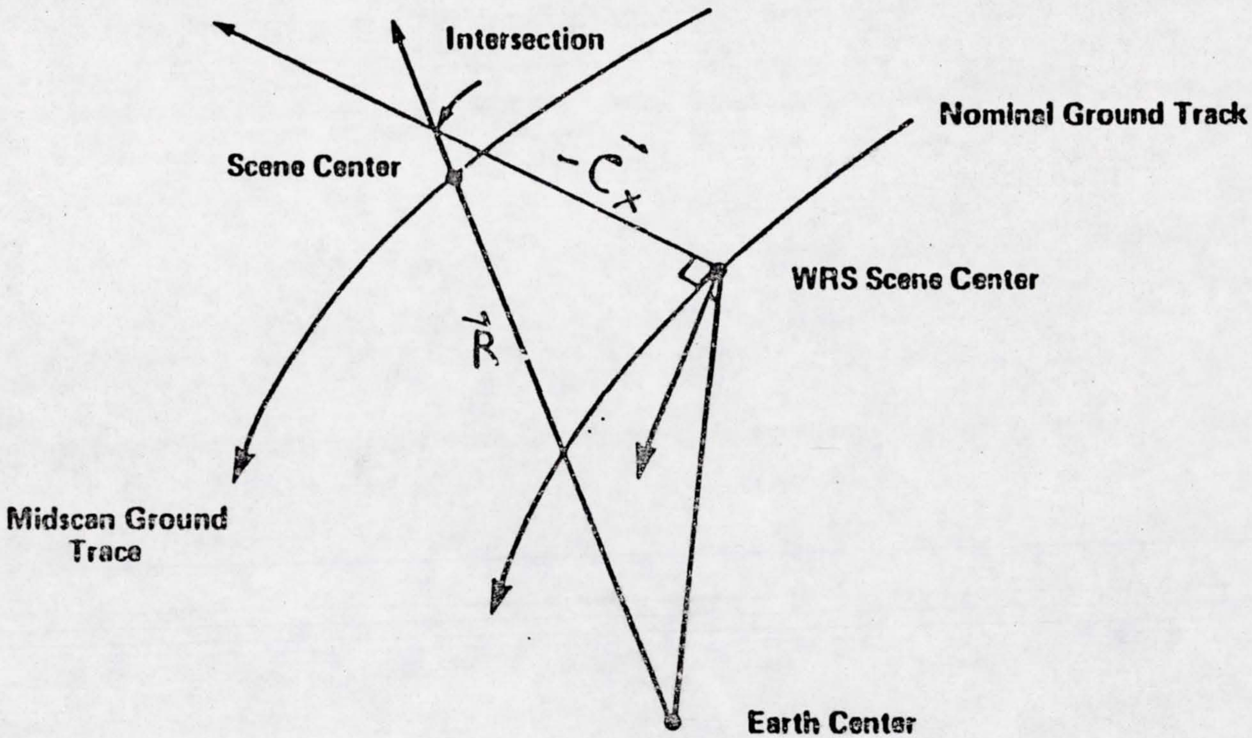


Example of Quaternion
In Small Angle Approximation

$$q_1 \cong \tfrac{1}{2}\theta_P$$
$$q_2 \cong \tfrac{1}{2}\theta_R$$
$$q_3 \cong \tfrac{1}{2}\theta_Y$$
$$q_4 \cong 1.0$$

Scene Center Calculation

- Scene Center Time: Time at Which X - Axis of Standard Coordinate System Is Intersected by a Radius Vector Through Midscan Ground Trace



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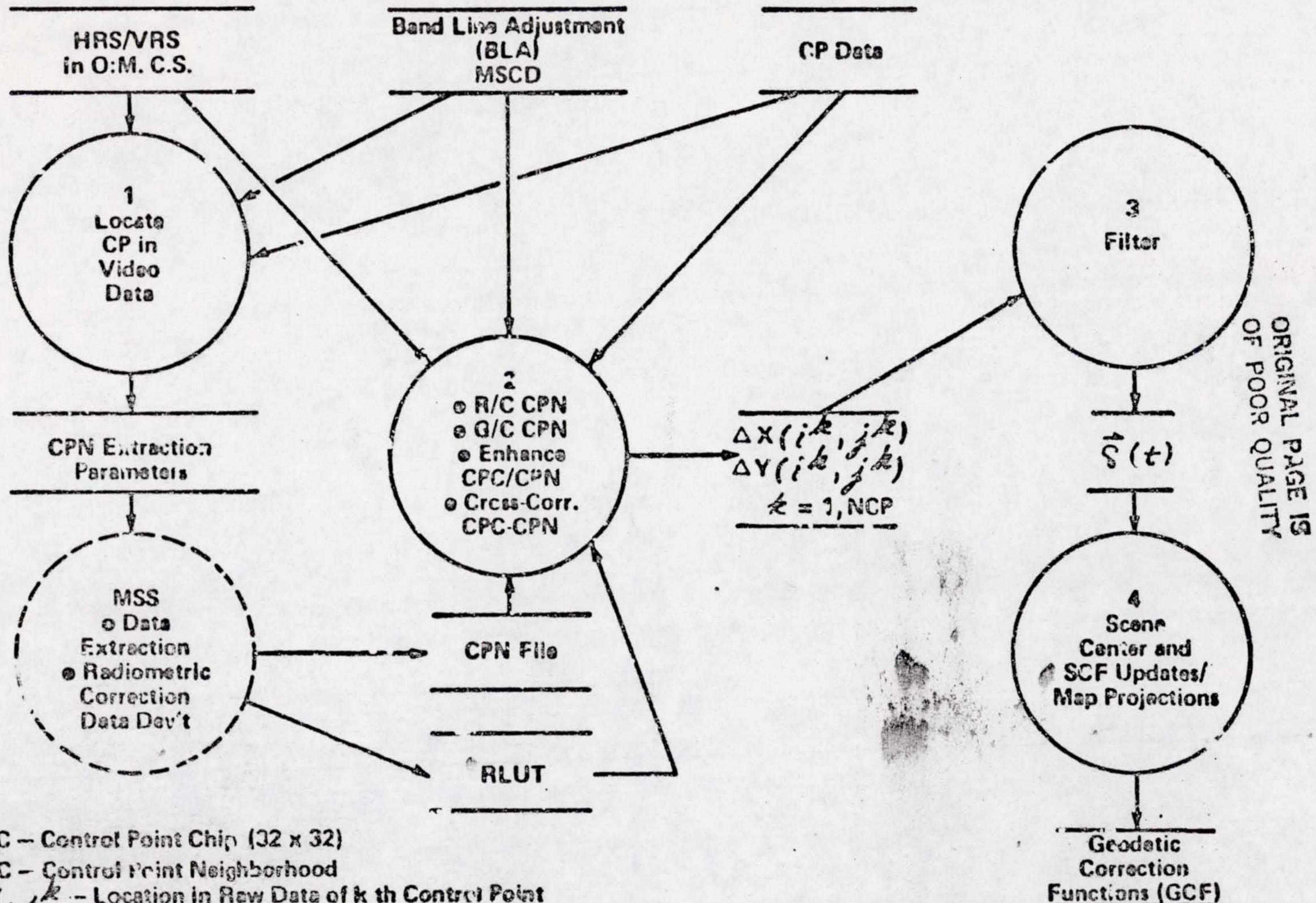
MSS Data Flow In GCDG



CPC – Control Point Chip (32 x 32)

CPC – Control Point Neighborhood

i^k, j^k – Location in Raw Data of k th Control Point

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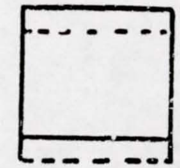
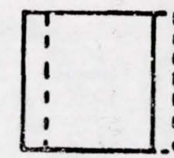
Properties/Effects Of $\vec{\delta}$ For Landsat-D MSS (Single Scene)

- **Constant $\vec{\delta}$**

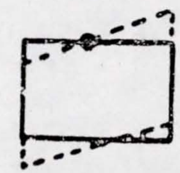
  - $\delta\alpha$, $\delta\theta_p$ — **Along Track Displacement**



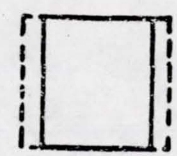
  - $\delta\beta$, $\delta\theta_r$ — **Cross Track Displacement**



  - $\delta\theta_y$ — **Along Track Asymmetry**



  - δr — **Cross Track Asymmetry (Magnification)**



- **Asymmetries Almost Linear and Odd Functions of X**
- **Displacements Large**
- **Asymmetries Small But Detectable (0.25 - 1.5 Pixel)**

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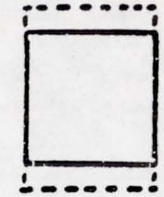
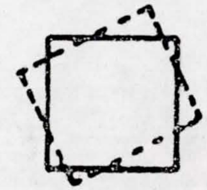
$\vec{\delta}$ Rates - All Asymmetric Image Distortions

– $\delta\dot{\alpha}, \delta\dot{\theta}_p$ – Along Track Asymmetry (Magnification)



– $\delta\dot{\beta}, \delta\dot{\theta}_r$ – Cross Track Asymmetry (Rotation or Yaw Plus Cross Track Skew)



– $\delta\dot{\theta}_y$ – Growth of Along Track Skew

– $\delta\dot{r}$ – Growth of Cross Track Magnification

- Asymmetries Almost Linear and Odd Functions of Y.
- Asymmetries Marginally Detectable (Less Than 0.1 Pixel, 90%)

Filter Variables

- $\delta\alpha$ and $\delta\theta_P$ Hard to Separate – Represented by Single Variable – δAT, For Along Track Translations
- $\delta\beta$ and $\delta\theta_R$ Hard to Separate – Represented by Single Variable δCT, for Cross Track Translations
- Hence a 6-Variable Filter:

Bias Name	Effect in Image	90% Error at Worst Point (Pixels)
δAT	Along Track Shift	$>$ 10
δCT	Cross Track Shift	$>$ 10
δr	Cross Track Magnification	$\sim$ 0.1
$\delta\theta_Y$	Along Track Skew	$\sim$ 0.8
$\delta\dot{AT}$	Along Track Magnification	$\sim$ 0.1
$\delta\dot{CT}$	Cross Track Skew	$\sim$ 0.1

Basis Of The MSS Filter

- Linearity of SCF with $\vec{\delta} = (\delta\alpha, \delta\beta, \delta\kappa, \delta\theta_p, \delta\theta_x, \delta\theta)$
- Availability of Analytic Partial Derivatives

$$\mu_{x\ell}(i,j) = \partial X(i,j) / \partial \delta_\ell$$
$$\mu_{y\ell}(i,j) = \partial Y(i,j) / \partial \delta_\ell$$

- $\Delta X(i,j) = \sum_\ell \mu_{x\ell}(i,j) \cdot \delta_\ell(i,j)$
- $\Delta Y(i,j) = \sum_\ell \mu_{y\ell}(i,j) \cdot \delta_\ell(i,j)$

Time Simply Related to i,j

- Above Suggests an Optimal Least Squares Filter, Based on Function:

$$NCP\left(\overline{\epsilon_x^2}/\sigma_x^2 + \overline{\epsilon_y^2}/\sigma_y^2\right) \equiv F(\vec{\delta})/\sigma_x^2$$

Where $\overline{\epsilon_q^2} = \frac{1}{NCP} \sum_{k=1}^{NCP} \left\{\Delta q^k - \sum_\ell \mu_{q\ell}(i^k, j^k) \cdot \delta_\ell(i^k, j^k)\right\}^2 \quad ; \; q = x, y$

and σ_q^2 = Variance of Image Noise/Measurements

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CHOOSING THE OPTIMAL VARIABLE SET

- X CORRECTION AND Y CORRECTION ARE ALMOST INDEPENDENT
- X CORRECTING BIASES: δ CT, δ R, $\delta \dot{C}T$,
  - COMPUTE X-QUALITY FOR
    1. ALL 3 VARIABLES
    2. δ CT AND EACH OF 2 INDIVIDUALS
    3. δ CT ALONE
  - RETAIN VARIABLE SET THAT PRODUCES BEST QUALITY
- Y CORRECTING BIASES: δ AT, $\delta \theta_Y$, $\delta \mathring{A}T$
  - PROCEED AS FOR X, USING Y-QUALITY
  - RETAIN VARIABLE SET THAT PRODUCES BEST QUALITY
- REPORT VARIABLE SET USED, X- AND Y- QUALITY

Quality Of Correction

- Definition of X-Quality:
  Residual Error in X at Worst Points in Scene (Corners)

- Definition of Y-Quality:
  Residual Error in Y at Worst Points in Scene (Corners)

- Semi-Analytic Functions for X and Y Quality Deduced for Given NCP and Spatial Distribution of CPs — Also Depend on σ_x, σ_y Directly

- X- and Y-Quality Deduced Dynamically and Used to Select Optimal Variable Set

- Outliers Removed in Usual Way

FILTER OUTPUTS

- STATE VECTOR ($\vec{S}$)
- COVARIANCE MATRIX
- ALONG TRACK, CROSS TRACK QUALITY MEASURES
- RESIDUALS AT CONTROL POINTS
- OUTLIER ENUMERATION
- VARIABLES ESTIMATED

GEOMETRIC CORRECTION CALIBRATION

- PURPOSE: IMPROVE SYSTEMATIC CORRECTION FOR SCENES LACKING CONTROL POINTS
- PARAMETERS TO BE CALIBRATED
  - MIRROR MODEL PARAMETERS
  - INSTRUMENT MISALIGNMENTS
  - IMAGE NOISE MATRIX ELEMENTS
  - A PRIORI STATISTICS OF THE SPACECRAFT PARAMETER BIASES
- CALIBRATION DATA - LONG TERM MEANS AND VARIANCES
  - MEAN AND VARIANCE OF LINE LENGTHS
  - MEANS AND VARIANCES OF SPACECRAFT PARAMETER BIASES
  - RESIDUALS AT CONTROL POINTS - MEANS AND VARIANCES OF RESIDUALS SORTED ON CROSS TRACK LOCATION

GEOMETRIC CORRECTION CALIBRATION (CONTINUED)

- CALIBRATION APPROACH
  - EFFECTS MIXED ON THE GROUND - SELECT SINGLE PARAMETER TO BE UPDATED
  - NON-ZERO MEANS OF SPACECRAFT PARAMETER BIASES POINT TO MISALIGNMENTS, MIRROR AMPLITUDE OR MIRROR VELOCITY ERRORS
  - VARIANCES OF SPACECRAFT PARAMETER BIASES PROVIDE STATISTICS FOR SELECTING OPTIMAL VARIABLE SET
  - CROSS TRACK PATTERNS IN THE RESIDUALS POINT TO MIRROR VELOCITY PROFILE ERRORS
  - DEVIATION OF MEAN LINE LENGTH FROM NOMINAL - MIRROR SPEED CORRECTION - NO IMPACT

Closing Remarks

John Barker

LOA List of Acronyms

AAT	Archival Ancillary (Data) Tape
ACCA	Automatic Cloud Cover Assessment
ACE	Attitude Control Electronics
ACS	Attitude Control System
ACT	Application Concept Test
A/D	Analog to Digital
ADCP	See ANDP
ADDS	Applications Developmental Data System
ADFS	Automated Digital Facsimile System
ADL	Applications Development Laboratory
ADP	Automatic Data Processing
ADPE	Automatic Data Processing Equipment
A&DS	Aerospace and Data Systems
ADS	Angular Displacement Sensor or Angle Detector Sensor
ADT	Ancillary Data Tape
AEM	Applications Exploratory Mission
AFGWC	Air Force Global Weather Central
AFOS	Automation of Field Operations and Services
AFPRO	Air Force Plant Representative Office
AG	Archive Generation
AGC	Automatic Gain Control
AGE	Aerospace Ground Equipment
AGS&PO	Aerospace Group Strategic Planning and Programs Office
Ahr	Ampere - hour
ALU	Algorithm Logic Unit
AMS	Attitude Measurement System
AN	Applications Notice
ANCP	See ANDP
ANDP	Ancillary Data Calculation Process
ANSI	American National Standards Institute
ANT	Ascending Node Table
AO	Announcement of Opportunity
AOIPS	Atmospheric and Oceanographic Image Processing System
AOP	Advanced Onboard Processor
AOS	Acquisition of Signal
AP	Applications Processor
AP	Array Processor
APFO	Aerial Photography Field Office
APL	Applied Physics Laboratory (John Hopkins Univ.)
APS	Antenna Positioning System
ASCII	American Standard Code for Information Interchange
ASPR	Aerospace Strategic Program Representation
ASPR	Armed Services Procurement Regulations
ASR	Automatic Send/Receive
AST	Asynchronous System Trap
ASVT	Applications System Verification and Transfer Project
AT	Acceptance Test
ATL	Applications Technology Laboratory
ATM	Antenna Test Model
ATM	Apollo Telescope Mount
ATP	Acceptance Test Plan
ATS	Applications Technology Satellite
AWG	American Wire Gauge
BARDJA	Boom Antenna Retention Deployment and Jettison Assembly
BAT	Bench Acceptance Test
BB	Build Baseline
BCU	Bus Coupling Unit
BDF	Block Data Format
BER	Bit Error Rate
BESS	Biological Experiment Scientific Satellite
BFR	Browse Film Recorder
BIC	Band Interleaved by Cylinder
BIL	Band Interleaved by Line
BIP	Band Interleaved by Pixel
BIW	Band Interleaved by Word
BOL	Beginning of Life
BOS	Beginning of Scan
BOT	Beginning of Tape
B&P	Bid and Proposal
BPA	Bus Protection Assembly
bpi	Bits per Inch
BPI	Bytes per Inch
bps	Bits per Second
BPS	Bytes per Second
BSE	Broadcast Satellite Experimental
BSQ	Band Sequential
BSR	Back Surface Radiator
BTC	Bench Test Cooler
BTCE	Bench Test and Calibration Equipment
BTE	Bench Test Equipment
B/U	Backup
B&W	Black and White
CAL	Configured Articles List
CAL	Calibration
CARETS	Central Atlantic Regional Ecological Test Site
CASH	Catalog of Available and Standard Hardware
CAT	Catalog
CCA	Cloud Cover Assessment
CCB	Configuration Control Board
CCC	Camera Controller Combiner

CCD	Charge Coupled Device
CCL	Closed Circuit Loop
CCM	Color Composite Master
CCN	Contract Change Notice
CCP	Cloud Cover Assessment Process
CCT	Computer Compatible Tape
CCT-A	CCT Containing Partially-Corrected Data
CCT-AH	CCT Containing Partially-Corrected MSS Sensor Data
CCT-AT	CCT Containing Partially-Corrected TM Senor Data
CCT-B	CCT Produced by ADDS
CCT-P	CCT Containing Fully-Corrected Data
CCT-PM	CCT Containing Fully-Corrected MSS Sensor Data
CCT-PT	CCT Containing Fully-Corrected TM Sensor Data
CDD	Cartridge Removable Diablo Disk Drive
C&DH	Command and Data Handling
CDHS	Command and Data Handling System
CDHSS	Command and Data Handling System Simulator
CDHSS I/U	CDHSS Interface Unit
CDR	Conceptual Design Review
CDR	Critical Design Review
CDRB	Conceptual Design Review Board
CDRL	Contract Data Requirements List
CEM	Controlled Environment Module
CFOV	Clear Field-of-View
CG	Center of Gravity
CI	Configuration Item
CLD	Cloud
CLL	Corrected Line Length
CM	Center of Mass
C.M.	Configuration Management
CMD	Command
CMI	Configuration Management Instruction
CMM	Command Memory Management
CMO	Configuration Management Office
COBOL	Common Business Oriented Language
COMP	Computer
C.P.	Center of Pressure
CP	Communication Processor
CP	Control Point
CPC	Control Point Chip
CPCI	Computer Program Configuration Item
CPD	Control Point Directory
CPDS	Computer Program Design Specification
CPD-U	Control Point Directory (Candidate for Permanent File)
CPG	Correction and Product Generation Software
CPL	Control Point Library
CPL-U	Control Point Library (Candidate for Permanent File)
cpm	Cards per Minute
CPM	Computer Personality Module
CPN	Control Point Neighborhood
CPN-G	Control Point Neighborhood for Geodetic Corrections
CPN-L	Control Point Neighborhood for Library Maintenance
CPN-M	Control Point Neighborhood for MSS
CPN-T	Control Point Neighborhood for TM
CPPT	CZCS Preprocessor Performance Tape
CPR	Cloud Physics Radiometer
CPU	Central Processing Unit

CR	Card Reader
CRC	Cyclic Redundancy Check
CRIS	Cosmic Ray Ionization Spectrometer
CRT	Cathode Ray Tube
CSA	Cropping, Subsampling and Averaging
CSC	Computer Sciences Corporation
CSE	Contractor Supplied Equipment
CSF	Control and Simulation Facility
CSS	Coarse Sun Sensor
CU	Central Unit
CY	Calendar Year
CZCS	Coastal Zone Color Scanner
D/A	Digital-to-Analog
DAS	Data Base Administration Subsystem
DAS^3	De-Centralized Automated Service Support System
DB	Data Base
DBIP	Data Base Interface Process
dBi	Antenna gain in decibels referenced to an Isotropic Antenna
dBm	Power in decibels referenced to one millimeter
DBMS	Data Base Management System
DBMS-10	DEC-10 System Software for Data Base Management
DC	Direct Current
DCP	Data Collection Platform
DCS	Data Collection System
DCST	Data Collection System Tape
DDG	Digital Display Generator
DDI	Digital Data Interconnect
DDL	Data Description Language
DDP	Digital Data Processor
DDP-C	Controlled Environment Module DDP
DDP-W	Wire-Wrapped DDP
DDR	Detailed Design Review
DDRB	Detailed Design Review Baseline
DEC	Digital Equipment Corporation
DEC-10	DEC-10 Computer
DEC-20	DEC-20 Computer
DECnet	Digital Equipment Corporation Communications Network
DECOM	Decommutator
DECOM	Decommutation Hardware Device
DEMUX	Demultiplexer
DFP	Data Formatter Processor
DFS/ADFS	Digital Facsimile System/Automated Digital Facsimile System
DIAL	Digital Image Analysis Laboratory
DICOMED	Film Recorder Vendor
DID	Digital Image Data
DIP	Dual Inline Package
DIPS	Digital Image Processing System
DKIO	Large Image Access Routines
D/L	Downlink
DMA	Direct Memory Access
DMF	Data Management Facility
DML	Data Management Language
DML	Data Manipulation Language
DMS	Data Management System

DMSP	Defense Meteorological Satellite Program
DOC	Data Operations Control
DOD	Department of Defense
DOD	Depth of Discharge
DOI	Department of the Interior
DOI/EDC	Department of the Interior/EROS Data Center
DOMSAT	Domestic Communications Satellite
DPM	Drafting Practices Manual
DPR	Design Problem Report
DPS	Data Processing System
DPS	DRRTS Process Software
DPSE	DRRTS Process Software Executive
DPU	Digital Processing Unit
DR11C	Programmed Input Output Interface Device for DEC Unibus
DR70	Direct Memory Access Interface Device for DEC Massbus
DR780	Direct Memory Access Interface Device for DEC VAX-11/780
DRIRU	Dry Rotor Inertial Reference Unit
DRRTS	Data Receive, Record and Transmit System
DS	Dimension (Telephone) System
DSC	Data Collection System
DSCS	Defense Satellite Communications System
DSCS	Desk Side Computer System
DSI	Digital Subsystem Interface Unit
DSL	Data Service Laboratory
DSM	Downlink Synchronization Module
DSSCI	Data Stripper-Serial Controller Interface
DSU	Digital Switching Unit
DTD	Digital Terrain Data
DTM	Digital Terrain Map
DTG	Digital Tape Generation
DTR	Daily Test Report
DTS	Digital Transmission System
DV	Digital Voltmeter
DX20	DEC Peripheral Interface Device
DXFP	Data Extraction and Formatting Process
EAGE	Electrical Aerospace Ground Equipment
EBCDIC	Extended Binary Coded Decimal Interchange Code
EBR	Electron Beam Recorder
EBRIC	Electronic Beam Recorder Image Correction
ECC	Error Correction Capability (HDDR)
ECEF	Earth-Centered-Earth-Fixed
ECI	Earth-Centered-Inertial
ECL	Emitter Coupled Logic
EDC	EROS Data Center
EDIPS	Electronic Digital Processing System
EDIPS	EDC Digital Image Processing System
EDP	Electronic Data (Digital) Processing
EDPS	Electronic Data Processing System
EED	Electro-Explosive Device
EF	Earth Fixed Coordinate System
EGRET	Explorer Gamma Ray Experiment Telescope
EGSE	Electrical Government Supplied Equipment
EI	Engineering Instruction
EIA	Electronic Industries Association
ELE	Elevation at Entry
ELS	End-of-Line Sync
ELX	Elevation at Exit
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ENA/DISA	Enable/Disable
EOB	End-of-Buffer
EOF	End-of-File
EOL	End-of-Life
EOM	End-of-Mission
EOP	Earth Observatory Program
EOP	End-of-Process
EORT	End-of-Roll Target
EOS	End-of-Scan
EOS	Earth Observation Systems
EOS	Earth Observations Satellite
EOS	End-of-Set
EO&SP	Earth Observatory and Shuttle Programs
EOT	End-of-Tape
EOV	End-of-Volume
EPA	Environmental Protection Agency
EPC	Electrical Power Conditioner
EPI	Euler Parameter Integration
EPS	Electrostatic Plotting Software
ER	Equipment Room
EREP	Earth Resources Equipment Package
EROS	Earth Resources Observation System or Satellite
ERS	Earth Resources Survey
ERTS	Earth Resources Technology Satellite
ESA	European Space Agency
ESR	Equipment Service Report
ESTEC	European Space Research and Technology Center
EU	Expander Unit
EVA	Extra-Vehicular Activity
EVAL	Earth Viewing Applications Laboratory
EWO	Engineering Work Order
FAIRS	Full Aperture Infrared Source
F&AO	Financial and Administrative Operations
FAS	Foreign Agricultural Service
FCS	File Control Service
FDD	Fixed (Cartridge) Diablo Disk (Drive)
FDR	Final Design Review
FFP	Federation of Functional Processors
FGS	Fine Guidance System
FHST	Fixed-Head Star Tracker
FID	Final Instrument Definition
FIFO	First-In, First-Out
FIPS	Federal Information Processing Standards
FM	Frequency Modulation
FM	Flight Model
FMEA	Failure Mode and Effects Analysis
FMS	Flight (Segment) Management Subsystem
FO	Flight Operations
FOC	Faint Object Camera
FORTRAN	Formula Translation

FOS	Field Operations Service
FOS	Flight Operations Subsystem
FOS	Faint Object Spectrograph
FOV	Field-of-View
FPA	Focal Plane Assembly
FPG	Final Product Generation
FPP	Floating Point Processor
FPS	Focal Plane Structure
FRD	Facilities Requirement Document
FRS	Film Recorder System
FRUSA/HASP	Flexible Roll-Up Solar Array/Hardened Solar Power System
FS	Flight Segment
FSCM	Federal Supply Code For Manufacturers
FSDF	Flight Segment Development Facility
FSEC	Fairchild Space and Electronics Company
FSK	Frequency Shift Keying
FSS	Flight Scheduling Subsystem
FSS	Flight Segment Simulator
FSS	Flight Support System
FSS	Fine Sun Sensor
FSS S/W	Flight Segment Simulator Software
FT	Fourier Transform
FTS	Federal Telephone System
FW	Fiscal Week
FY	Fiscal Year
FYI	For Your Information
G/C	Geometric Correction
GCD	Geodetic Correction Data or Geometric Correction Data
GCDG	Geodetic Correction Data Generation
GCM	Geometric Correction Matrices
GCM	Geometric Correction Matrix
GCO	Geometric Correction Operator
GCOVS	GCO Verification System
GCP	Geodetic Control Point
GCP	Ground Control Point
GDHS	Ground Data Handling System
GDT	Graphics Display Terminal
GE	General Electric
GE70	GE Interface Device for DR780
GECP	Geometric Correction Process
GEOREF	Geographic Reference
GES	Ground Electronic Specification
GETSCO	General Electric Technical Service Company
GFE	Government Furnished Equipment
GFIT	Goddard Film Inventory Tape
GFP	Government Furnished Property
GHIT	Goddard HDT Inventory Tape
GHz	Gigahertz (10^9)
GI	General Instruction
GIA	Government Inspection Agency
GM	General Manager
GMF	GCO Microcode File
GMP	Geometric Correction Matrix Calculation Process
GMS	Ground (Segment) Management Subsystem
GMT	Greenwich Mean Time
GOES	Geostationary Operational Environmental Satellite
GPC	General Purpose Console
GPE	Ground Processing Equipment
GPIP	General Purpose Information Processor
GPS	Global Positioning System
GPT	General Purpose Transformation
GRE	Gamma Ray Explorer
GRFP	Graphite Filled Epoxy
GS	Ground Segment
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
GSSS	Ground Support System Software
GSTDN	Ground Spaceflight Tracking and Data Network
HAAT	Header, Ancillary, Annotation, Trailer
HATT-L	HATT for Library Maintenance
HAC	HDDR Assignment and Control
HAT	Header Annotation, Trailer
HAL	High-Order Aerospace Language
HCMM	Heat Capacity Mapping Mission
HD	HDT Duplication
HDDR	High Density Digital Recorder
HDDT	High Density Digital Tape
HDE	HDT-R Directory Extractor
HDT	High Density Tape
HDT-A	HDT-Archive Format (Partially corrected radiometrically but not geometrically)
HDT-AM	HDT-A for MSS Sensor Data
HDT-AMC	Copy of HDT-A for MSS Sensor Data
HDT-AT	HDT-A for TM Sensor Data
HDT-ATC	Copy of HDT-A for TM Sensor Data
HDT-I	HDT (Data) Interval
HDT-P	HDT-Product Format (Fully corrected)
HDT-PT	HDT-P for TM Sensor Data
HDT-PTC	Copy of HDT-P for TM Sensor Data
HDTR	High Density Tape Recorder
HDT-R	HDT-Raw Data as recorded in DRRTS
HDT-RM	HDT-R for MSS Sensor Data
HDT-RT	HDT-R for TM Sensor Data
HDT-S	HDT Recorded at White Sands
HDT-SM	HDT-S for MSS Sensor Data
HDT-ST	HDT-S for TM Sensor Data
HgCdTe	Mercury Cadmium Telluride
HIPO	Hierarchy Input Process Output
HRFR	High Resolution Film Recorder
HSCE	High Speed Control Element
HSI	High Speed Interface
HV	Host Vehicle (Landsat-D)
H/W	Hardware
Hz	Hertz (cycles per second)
IAC	Image Analyzer Console
IAP	Integrated Analysis Plan
IAT	Image Analysis Terminal
IAT	Image Annotation Tape
IB	Integration Baseline

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ICCD	Intensified Charge Coupled Device
ICD	Interface Control Document
ICS	Image Correction Support Software
ICS	Interactive Computer Simulator
ID	Identification
IDA	Image Data Acquisition
IDB	Identification Burst
IDBS	International Data Base Systems
IDS	Image Data System
IDT	Investigation Definition Team
IDT	Image Display Terminal
IDT	Industrial Data Terminal Corporation
IDT	Image Data Transmission
I/F	Interface
IF	Intermediate Frequency
IFD	In-Flight Disconnect
IFOV	Instantaneous Field-of-View
IG	Initial Gap
IGF	Image Generation Facility
IIGS	Initial Image Generation Subsystem
IIRV	Improved Inter-Range Vectors
IIS (I^2S)	International Imaging Systems
IM	Information Management
IM	Instrument Module
IMPAC	Image Processing and Analysis Center
IMS	Information Management Subsystem
IMSC	Information Management Subsystem Computer
IMSFCC	Information Management Subsystem FFP Control Computer
IMU	Image Memory Unit
InSb	Indium Antimonide
INTRALAB	Information Transfer Laboratory
I/O	Input/Output
IPC	Initial Product Creation
IPCS	Information Production Control System
IPD	Information Processing Division
IPF	Image Processing Facility
ips	Inches per Second
IPS	Image Processing Subsystem
IPS-1	IPS String No. 1 Computers
IPS-2	IPS String No. 2 Computers
IPSC	IPS Computer
IQL	Interactive Query Language
IR	Infrared
IRB	Integrated Requirements Board
IR&D	Independent Research and Development
IRD	Interface Requirements Document
IRFPA	Infrared Focal Plane Assembly
IRG	Inter-Record Gap
IRIG	Inter-Range Instrumentation Group Time Code
IRIG-A	IRIG Time Code Series A
IRP	Infrared Photometer
IRQ	Interrupt Request
IRU	Inertial Reference Unit
IS	Input Subsystem
ISA	Instrument Standard of America
ISAM	Index Sequential Access Method
ISM	Interface Switching Module
ISS	Image Generation Facility Software Subset
ISU	Input Scanner Unit
IT	Integration Test
I&T	Integration and Test
ITD	Inception-to-Date
ITD	Incurred-to-Date
ITP	Integration Test Plan
IU	Interface Unit
IUE	International Ultraviolet Explorer
IUS	Interim Upper Stage
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
K	A Thousand
K	1024 (Memory Usage Only)
Kb	Kilobit
KB	Kilobyte
Kbps	Kilobits per Second
KBPS	Kilobytes per Second
KCRT	Keyboard Cathode Ray Tube
KL10	CPU for DEC-10 Computer
km	Kilometer
KS	Key Station
KSA	Ku-band Single Access
KSC	Kennedy Space Center
KW	Kilowords
LA36	DEC Hardcopy Terminal
LACIE	Large Area Crop Inventory Equipment
LANDSAT	Land Satellite
LaRC	Langley Research Center
LAS	Landsat-D Assessment System
LAT	Latitude
LBP	Library Build Process
LBR	Laser Beam Recorder
LCP	Left-hand Circularly Polarized
LED	Light-Emitting Diode
LFC	Left-Fill Count
LIDU	Large Image Display Utility
LIFO	Last-In, First-Out
LLA	Adjusted Line Length
LLC	Line Length Code
LM	Library Maintenance
LM	Line Monitor
LMM	Landsat Mission Management
LMSC	Lockheed Missile and Space Corporation
LOE	Level of Effort
LONG	Longitude
LOS	Line of Sight
LOS	Loss of Signal
LPC	Longitudinal Parity Check
LPM	Line Point Marker
LPM	Lines Per Minute
LPM	Load Point Marker
LRA	Laser Retrodirector Array

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LRC	Longitudinal Redundancy Check
LRD	Laser Retrodirector
LSB	Least Significant Bit
LSD	Landsat-D
LS3	Landsat 3
LTC	Light Transfer Characteristics
LTTS	Long-Term Tape Storage Facility
LTU	Line Test Unit
LUN	Logical Unit Number
LV	Launch Vehicle
M	Mega-
M	Million
MA	Multiple Access
MACS	Modular Attitude Control System
MAG	MSS Archival Product Generation
MAP	Macro Array Processor
MASSBUS	High Speed Bus for DEC Equipment
MATSCO	Management and Technical Services Company
Mb	Megabit
MB	Megabyte
MBA	MASSBUS Adaptor
Mbps	Megabits per Second
MCC	Mission Control Center
MCCA	Manual Cloud Cover Assessment Package
MCR	Monitor Console Routine
MCTF	Mission Contractor Test Facility
M&DO	Mission and Data Operations
M&DOD	Mission and Data Operations Directorate
MDM	Multiplex-Demultiplex
MDP	Master Data Processor
MEM	Module Exchange Mechanism
MERITS	Marshall Earth Resources Information Transfer System
METSAT	Meteorological Satellite
MFB	Major Frame Buffer
MFD	Master File Directory
MFS	Major Frame Synchronization
MGSE	Mechanical Government Supplied Equipment
MHS	MSS/HDDR Service
MHW	Multi-Hundred Watt
MHz	Megahertz (10^6)
MIF	Master Information File
MIP	Management Information Process
MIPS	MSS Image Processing System
MIPS	Mega-Instructions per Second
MIS	Mission Interface Subsystem
MIT	Master Information Table
MJF	Major Frame
mm	Millimeter
MM	Minutes
MMF	Mission Management Facility
MMFCC	Mission Management Facility Control Computer
MMF-M	MSS Mission Management Facility
MMF-T	TM Mission Management Facility
MMS	Mission Management System
MMS	Multi-Mission Modular Spacecraft
MMU	Memory Management Unit
MNFS	Minor Frame Synchronization
M&O	Maintenance and Operations
MODEM	Modulator/Demodulator
MOI	Moments of Inertia
MOL	Manned Orbiting Laboratory
MOM	Mission Operations Manager
MOPA	Mega-Operations per Second
MOR	Mission Operations Review
MOU	Memorandum of Understanding
MPP	MSS Preprocessor
MPS	Mission Planning System
MPS	Modular Power Subsystem
MPT	Maximum Power Tracker
MPY	Multiply
MRA	Maintenance Requirements Analysis
MRAM	Maintenance Requirements Analysis Matrix
MRC	Master Reference Cube
MRS	Module Reference System
MS	Mirror Sweep
MSB	Most Significant Bit
MSC	Manned Space Center
MSCD-M	MSS Mirror Scan Correction Data
MSCD-T	TM Mirror Scan Correction Data
MSCO	Mission Support Coordination Office
MSC	Matrix Switch Control
MSEC	Millisecond
MSFC	Marshall Space Flight Center
MSR	Monthly Status Review
MSS	Module Support Structure
MSS	Multispectral Scanner
MSS-A	MSS Archival Data
MSW	Matrix Switch
MT	Magnetic Tape
MTBF	Mean Time Between Failures
MTF	Modulation Transfer Function
MTL	Material
MTM	Mechanical Test Module
MTP	MSS Telemetry Processor
MTTR	Mean Time to Repair
MTU	Magnetic Tape Unit
MUX	Multiplexer
MW	Megawords
N_2	Purified and Filtered Gaseous Nitrogen
N/A	Not Applicable
NAK	Negative Acknowledgement
NAPPS	Nimbus/AEM Preprocessor System
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications Network
NASTRAN	NASA Structural Analysis (Program)
NASTRAN	NASA Transient Analysis System
NBTR	Narrow Band Tape Recorder
NCC	National Climatic Center
NCC	Network Control Center
NCCS	Network Control Center Subsystem
NCIC	National Cartographic Information Center

ND	Networks Directorate
NDF	Neutral Density Filter
NDPF	NASA Data Processing Facility
NDS	Navigation Data Satellite
NDS	Navigational Development Satellite
NESS	National Environmental Satellite Service
NMI	NASA Management Instructions
NOAA	National Oceanic and Atmospheric Administration
NOCC	Network Operations Control Center
NOSS	National Oceanographic Satellite System
NRC	Nuclear Regulatory Commission
NRZ	Non-Return to Zero
NRZI	Non-Return to Zero Incrementing
NRZ-L	Non-Return to Zero-Level
NSCI	NASA Serial Controller for Input (now SPDI)
NSCO	NASA Serial Controller for Output (now PSDO)
NSSC-1	NASA Standard Spacecraft Computer - Model 1
NSSDC	National Space Science Data Center
NTR	New Technology Representative
NTSC	National Television System Committee
NTTF	Network Test and Training Facility
NTTF	NASA Tracking and Telemetry Facility
OAO	Orbital Astronomy Observatory
OAO	OAO Corporation
OAS	Orbit Adjust Subsystem
OBC	Onboard Computer
OBP	Onboard Processor
OCB	Operational Configuration Baseline
OCC	Operations Control Center
OCD	Operator Control and Display
OCG	Orbit Computations Group
OCR	Optical Character Recognition
ODF	Orbit Determination Facility
ODP	Online Display Process
ODT	Online Debugging Tool
O&M	Operations and Maintenance
OFLS	Offline System
ONLS	Online System
OPS	Operations
O/S	Operations Supervisor
OS	Operating System
OSCD	Orbital Support Computing Division
OSO	Orbiting Solar Observatory
OSR	Optical Solar Reflector
OSS	Office of Space Science
OSS	Operating System Software
OTA	Optical Telescope Assembly
OTDA	Office of Tracking and Data Acquisition
PA	Public Address
PAO	Public Affairs Office
PAM	Pulse Amplitude Modulation
PATH	Orbital Path
P/B	Playback
PBX	Private Branch Exchange
PC	Production Control
PC	Program Counter
PC	Printed Circuit
PCB	Printed Circuit Board
PCD	Payload Correction Data
PCD	Photon Counting Detector
PCD-M	MSS Payload Correction Data
PCD-T	TM Payload Correction Data
PCE	Pipeline Control Executive
PCM	Pulse Code Modulated
PCP	Product Control Procure
PCP	Program Control Procedure
PCS	Payload Correction Subsystem
PCU	Power Control Unit
PD	Payload Disconnect
PD	Programmable Decommutator
PDF	Programmable Data Formatter
PDL	Program Design Language
PDP	Programmable Digital Processor
PDP	Peripheral Data Product
PDR	Preliminary Design Review
PDR	Problem/Defect Report
PDSS	Precision Digital Sun Sensor
PDU	Power Distribution Unit
PE	Performance Evaluation
PE	Phase Encoded
P&E	Plant and Equipment
PES	Performance Evaluation Subsystem
PET	Predicted Ephemeris Tape
P/F	Protoflight
PFD	Pre-Flight Disconnect
PF&F	Protoflight and Flight
PFI	Program Funding Instructions
PGCOP	Product Generation CCT Output Process
PGHIP	Product Generation HDT Input Process
PGHSM	Product Generation HDT-P Simulator
PGLOP	Product Generation LBR Output Process
PGLSM	Product Generation LBR Simulator
PGM	Program Manager
PGMON	Product Generation Pipeline Monitor Process
PGP	Product Generation Process
PGS	Product Generation Subsystem
P/I	Policy/Instruction
PI	Principal Investigator
PIF	Pseudo Image File
PIGP	Pseudo Image Generation Program
PIL	Pixel Interleaved by Line
PIO	Programmed Input Output
PIP	Peripheral Interchange Program
PIR	Program Information Request/Release
PIXEL	Picture Element
PKG	Package Design Specification
P/L	Payload
PLACE	Post Landsat-D Advanced Concepts Evaluation
PM	Preventive Maintenance
PM	Propulsion Module
PMB	Program Management Budget
PMD	Post-Mortem Dump

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PM/FL	Performance Monitor/Fault Location
PMM	Program Maintenance Manual
PMP	Premodulation Processor
PMT	Photomultiplier Tube
PN	Pseudo Noise
PO	Project Office
PO	Purchase Order
POCC	Payload Operations Control Center
POD	Project Operations Directors
POP	Project Operating Plan
PORTS	Preliminary Operations Requirements and Testing Support
POWO	Purchase Order Work Order
PPL	Photo Processing Lab
PPL	Preferred Parts List
PPO	Program Participation/Opportunities System
PPS	Photographic Processing Subsystem
PRMIS	Printing Resource Management Information
PRN	Pseudo Random Noise
PRO	Payload Receiving Operations
PROM	Programmable Read-Only Memory
PRP	Performance Recognition Program
PRU	Power Regulator Unit
PS	Polar Stereographic
PSDO	Parallel-to-Serial Data Output Device
PSF	Photo/Shipping Support Facility
PSK	Phase Shift Keying
PSM	Programmable Sync Module
PSR	Project Status Review
PSU	Power Supply Unit
PSU	Power Switching Unit
PVS	Pressure Vessel Spacecraft
PWB	Printed Wiring Board
PWN	Pulse Width Modulated
Q&A	Qualification and Acceptance
QA	Quality Assurance/Assessment
QAF	Quality Assessment Film
QAP	Quality Assessment Process
QAP	Quality Assurance Procedure
QAP	Qualification and Acceptance Program
QC	Quality Control
QFP	Quality Assurance Film Generation Process
QIO	Queued Request for Input/Output
QIO	Queue Input/Output Process
QLD	Quick Look Display
QLM	Quick-Look Monitor Unit
QLP	Quick-Look Processor
QLPS	Quick-Look Processing System
QPSK	Quadrative Phase Shift Keyed
QRWO	Quick-Reaction Work Order
QSL	Quarter Scan Line
RAA	Reformating Ancillary Annotation
RAM	Random Access Memory
RBV	Return Beam Vidicon
RC	Radiometric Correction
RCFP	Radiometric Correction Function Calculation Process
RCHP	Right-Hand Circularly Polarized
RCP	Registration or Relative Control Point
RCP	Right-Hand Circularly Polarized
RCV	Receive
R&D	Research and Development
RDCP	Radiometric Corrected Process
RDCP	Radiometric Function Calculation Process
RDT	Raw Data Tape
REC	Record
REM	Rocket Engine Module
RF	Radio Frequency
RFC	Right-Fill Count
RFH	Request for Hire
RFOV	Resolution Field-of-View
RFP	Request for Proposal
RH780	Massbus Adaptor for DEC VAX-11/780
RID	Review Item Discrepancy
RIU	Remote Interface Unit
RLUT	Radiometric Lookup Table
RMS	Remote Manipulator System
RMS	Root Mean Square
RMS	Record Management Services
ROM	Read-Only Memory
ROW	Geographic Frame Reference
RP06	DEC 176 MB Disk or Removable Disk Storage Unit
RP07	DEC 283 MB Disk
R/PA	Receiver/Processor Assembly (GPS)
R&PA	Reliability and Product Assurance
RPM	Revolutions Per Minute
RPP	RBV Preprocessor
R&QA	Reliability and Quality Assurance
RSE	Receiving Site Equipment
RSE	Remote Site Equipment
RSX-11M	Multi-Tasking Operating System Software
R/T	Real-Time
RTG	Radiosotope Thermoelectric Generator
RTTS	Real-Time Test System
RX	Receive
SA	Single Access
SA	Solar Array
SAD	Solar Array Drive
SADAPTA	Solar Array Drive and Power Transfer Assembly
SAIL	Space Applications and Information Library
SARJA	Solar Array Retention, Deployment and Jettison Assembly
SB	Stage Baseline
SBC	Single Board Computer
SBI	Synchronous Backplane Interconnect
SBRC	Santa Barbara Research Center
SBS	Space Background Simulator
SBU	Strategic Business Unit
S/C	Spacecraft
SC	Signal Conditioning
SCA	Signal Conditional Assembly
SCAMA	Switching, Conferencing and Monitoring Arrangement

SCCB	Software Change Control Board
SCD	Systematic Correction Data
SCHS	Spacecraft Hardware Simulator (MSS Simulator)
SCI	Serial Control Interface
SCII	Serial Control Interface for Input (now SPDI)
SCIO	Serial Control Interface for Output (now PSDO)
SCL	Subcontract Labor
SCM	Systematic Correction Matrix
SCP	Sun Calibration Process
SCR	Scaler Control Register
SCR	Software Change Request
SC&SU	Signal Conditioning and Switching Unit (SU)
SCT	System Control Terminal
SD	Space Division
SDF	Software Development Facility
SDHS	Satellite Data Handling System
SDISS	Satellite Data Ingest and Storage Subsystem
SDSB	Satellite Data Services Branch
SEAM	Software Engineering and Management Program
Sec	Seconds of Arc
SECO	Secondary Electron Conduction Orthicon
SEOPS	Standard Earth Observation Package Satellite
SEOS	Synchronous Earth Observation Satellite
SI	Science Instruments
SIAT	Special Image Annotation Tape
SICM	Science Instrument Central Module
SIDU	Small Image Display Utility
SIF	Simulation Image File
SIM	Simulator
SIP	System Image Preservation
SIRD	Support Instrumentation Requirement Document
SIU	Sectorizer Ingest Unit
SLAT	Spacecraft Location and Attitude Tape
SLC	Scan Line Corrector
SLER	Synch Loss Error Rate
SLP	Source Language Input Program
SLS	Scan Line Sync
SLS	Start-of-Line Sync
SMA	S-Band Multiple Access
SMA	Scan Mirror Assembly
SMM	Solar Maximum Mission
SM&O	Support Maintenance and Operations
SMP	Scan Monitor Pulse
SMR	Software Modification Record
SMSA	Standard Metropolitan Statistical Area
S/N	Signal-to-Noise Ratio
SNR	Signal-to-Noise Ratio
SOM	Space Oblique Mercator
SOP	Standard Operating Procedure
SOW	Statement of Work
SP	Stack Pointer
SPC	Small Peripheral Controller
SPD	DEC Software Product Description
SPDI	Serial-to-Parallel Data Input Device
SPM	Sub-Project Manager
SPP	Special Purpose Processor
SPR	Software Problem Report
SPRD	Site Preparation Requirements Document
SPS	Segment Processing Subsystem
SPU	Scene Processing Unit
SQA	Software Quality Assurance
SRCDR	Software Requirements and Conceptual Design Review
SRCDS	Software Requirements and Conceptual Design Specification
SRR	System Requirements Review
SRS	Software Requirements Specification
SRS	System Requirement Specification
SRT	Supporting Research and Technology
SS	Seconds
S/S	Subsystem
SSA	S-Band Single Access
SSC	Science Support Center
SSDA	Sequential Similarity Detection Algorithm
SSM	Support Systems Module
SSO	Space System Operations
SSRR	Systems Software Requirements Review
SST	Synchronous System Trap
ST	Space Telescope
STACC	Standard Telemetry and Command Components
STACC-CU	STACC Central Unit
STACC-STINT	STACC Interface Unit
STC	System Test Console
STD	System Test Director
STD	Standard
STDL	System Test and Operation Language
STDN	Spaceflight Tracking and Data Network
STEP	Space Technology Engineering Program
STINT	Standard Interface for Onboard Computer
STINT	STACC Interface Unit
STOCC	Space Telescope Operations Control Center
STOL	System Test and Operations Language
STP	System Test Plan
STR	Standard S/C Telemetry Recorder
STR	Standard Tape Recorder
STR	System Test Review
STS	Space Transportation System
STS	Shuttle Transportation System
STSOC	Space Telescope Scientific Operations Center
SU	Switching Unit
SVS	Space Vehicle Specification
S/W	Software
SWG	Science Working Group
SYCI	System Corrected Images
TA	Transistor Adaptor
TAC	Telemetry and Command
TAC	TM Adaptive Capability
TAG	TM Archival Product Generation
TAM	Three Axis Magnetometer
TAS	Tape Archive and Storage
TBA	To Be Announced
TBD	To Be Determined
TBD	To Be Defined
TBR	To Be Resolved

TBS	To Be Supplied
TBV	To Be Verified
T/C	Time Code
TCC	Time Code Controller
TCG	Time Code Generator
TCI/OSC	Time Code In/Oscillator
TCOM	Army Test and Evaluation Command
TCO/PAN	Time Code Out/Panel
TCS	Thermal Control System
TCU	Time Code Unit
T&D	Test and Diagnostic
TD	Test Directives
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
T&E	Test and Evaluation
TEP	Telemetry Extraction Process
TGS	Transportable Ground Station
TIPS	TM Image Processing System
TIROS-N	Television Infrared Observing System
TIS	Technical Information Series
TLM	Telemetry
TM	Thematic Mapper
TM	Telemetry
TMV	Telemetry Volts
TOD	True-of-Date
TP	Telemetry Processor
TPG	Test Pattern Generator
TPL	Test Plan
TR	Tape Recorder
TRB	Test Review Board
TRF	Tracking and Receiving Facility
TRK	Track (HDDR)
TRKG	Tracking
TRP	Technical Recognition Program
TRW	TRW Defense and Space Systems Group
T/S	Thermal/Structural
TSIM	Test and Simulation Subsystem
TSSC	Technical Support Services Company
TSSF	Tape Staging and Storage Facility
TTA	Triangular Transition Adaptor
TT&C	Telemetry Tracking and Command
TTL	Transistor Logic Device
TTY	Teletype Operator Console
TU45	1600 bpi Magnetic Tape Unit
TU72	6250 bpi Magnetic Tape Unit
TU78	6250 bpi Magnetic Tape Unit
TV	Television
TWT	Traveling Wave Tube
TWTA	Traveling Wave Tube Amplifier
TX	Transmit
UARS	Upper Atmosphere Research Satellite
UBA	Unibus Adaptor
UBC	Unit Block Controller
UDDPM	Unload DDP Module
UDF	Unit Development Folder
UFD	User File Directory
UHF	Ultra High Frequency
UIC	User Identification Code
U/L	Uplink
UNIBUS	Universal Bus
UQPSK	Unbalanced Quadrature
USART	Universal Synchronous Asynchronous Receiver Transmitter
USB	Upper Side-Band
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UTC	Universal Time Coordinated
UTM	Universal Transverse Mercator
VA	Value Analysis
VAC	Volts, Alternating Current
VAP	Verification Acceptance Program
VAX-11/780	Virtual Address Extension DEC Model Computer 11/780
VCO	Voltage-Controlled Oscillator
VCRI	Verification Cross-Reference Index
VDC	Volts, Direct Current
VE	Value Engineering
VHF	Very High Frequency
VHRR	Very High Resolution Radiometer
VICAR	Video Image Communication and Retrieval
VIP	Virtually Interfaced Peripheral
VM	Value Management
VMS	Virtual Memory (Operating) System
VPASS	Video Processor and Sync Seperator
VPIR	Video Processor/Image Recorder
V/T	Vacuum Thermal
VT	Verification Test
VT78	Intelligent CRT Terminal
VT100	Non-Intelligent CRT Terminal
VTR	Video Tape Recorder
W/B	Wideband
WBM	Wideband Module
WBS	Work Breakdown Structure
WBSS	Wideband Subsystem
WBVT	Wide Band Video Tape
WBVTR	Wide Band Video Tape Recorder
WCS	Writeable Control Store
WFC	Wide-Field Camera
WO	Work Order
WPC	Word Processor Center
WPM	Work Package Manager
WRS	World Reference System
WSMR	White Sands Missile Range
WTR	Western Test Range
XMIT	Transmit
XMTR	Transmitter
Z	Zulu Time (GMT)
ZTS	Zoom Transfer Scoop
ZWC	Zero Word Count
μ	Micro-
μm	Micrometer (10^{-6} Meter)
μp	Microprocessor
μS	Microsecond

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LAS Software Functions (Partial Listing)

BAYES	Max. Likelihood Classification
BINARY	7 Functions: +, -, *, /, and, or, XOR
CALAMP	Analyze CAL Lamp Data
CANAL	Canonical Analysis
CHAROUT	Writes Annotation to Bit Plane
CLASSMAP	Generate Class Map Film Product
CLUSTER	Clustering
COLGEN	Generate Pseudo Color Table
COLSLIC	Movable Zero Band in Color LUT
COMBCLS	Combine Class
CONCAT	Concatenate Images
CONTOUR	Contour Image
CONVOLVE	Convolve Image (Smoothing)
COPY	Copy or Subset Image
COVAR	Covariance Matrix
CURSTRK	Figure Drawing with a Cursor (Graphics Proc.)
DESPIKE	Remove Spikes
DISCRIM	Discriment Analysis
DROPCLS	Delete Class
DROPSITE	Delete Training Site
EDGE	Extract Edges in Image
EDGECORR	Register Images by Edge Correlation
EDITSITE	Edit Training Site Coordinates
FFT1	1-Dimensional Fourier Transform
FFT1FL	1-Dimensional Fourier Transform Filter
FFT2	2-Dimensional Fourier Transform
FFT2FL	2-Dimensional Fourier Transform Filter
FIGLPEN	Figure Drawing with a Light Pen (Graphics Proc.)
FILM	Generate Film Product
FIT	Scale Image by Histogram
FLICKER	Blink Mode Display
FROMTV	Quick Copy of IAT to Disk
FT2PIX	Generate 2-Dimensional Fourier Display
FT1PIX	Generate 1-Dimensional Fourier Display
GCDG	Generate Geometric Correction Data
GEOM	Perform Geometric Transformation (Rubber Sheet) for LAS
GRAPHICS	Graphic Functions Via Console Button
GREYREG	Register Images by Grey Level Correlation
GRSLIC	Movable Zero Band in LUT
HINDU	Histogram Inspired Cluster
HISTEQ	Histogram Equalization RLUT Generation
JITTER	Analyze Jitter Effects
KARLOV	Karhunen-Loeve Transform
LINEOFF	Line Offset Correction
LINEREPR	Repair Bad Lines
LIST	List and Histogram Image Window
LISTSTAT	List Stats File
LUTEDT	Edits LUT File
LUTLOD	Load Specified LUT from LUT Disk File
LUTSAV	Save LUT on Disk File
MASKSTAT	Statistics of Mask Image
MEDFIL	Perform Median Filtering
MINDIST	Minimum Distance Classification
MOSAIC	Mosaic Images
MSSA2P	Resample MSS A-Image to P-Image
PARALL	Parallelpiped Classification
PFILM	Generate P-Type Film Product
POLYSITE	Polygonal Site Selections
PSEUDO	Load Pseudo Color Tables (LUTLOD Proc.)
RADIOM	Apply RLUT to Image
RECORD	Copies TV to TV (Thru LUT Optional)
RENCLS	Rename Class
RLUT	TM A-Priori RLUT Generation
SAVIAT	Saves IAT B/W Configuration
SCALE	Convert Halfword Image to BYTE Image
SCANNER	Read Scanner/Digitizer
SCDFT	Perform Fourier Analysis of SCD HFM
SCROLL	Scroll Disk Image to IAT's
SEGMOFF	Segment Offset Correction
SEGMREPR	Repair Image Blemish
SETTV	Redefines IAT B/W Configuration
SHADE	Shade Plot of Image Window
SITES	Rectangular Site Selections
SPLIT	Split Screen Operation
STATS	Generate Stats File (Training Site)
STRETCH	Stretch Image Contrast
TESTGEN	Generate Test Images
TIEPTS	Generate Control Grid for Resampling
TMA2P	Resample TM A-Image to P-Image
TMHIST	Histograms of TM Image for RLUT
TOTV	Quick Copy of 'TV-Size' Image to IAT
TRANSDIV	Transform Divergence
UMAP	Uniformity Mapping
UNARY	5 Functions: +, *, NOT, EXP, LOG
VEGGIN	Vegetative Index
WTGEN	Weight Generator for FFT2FL
XFERSITE	Transfer Training Site
ZOOM	Enlarge or Reduce Image

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